Board of Education, South Kensington.

CATALOGUE
OF THE
MECHANICAL ENGINEERING COLLECTION
IN THE
SCIENCE DIVISION
OF THE
VICTORIA AND ALBERT MUSEUM,
SOUTH KENSINGTON.

WITH DESCRIPTIVE AND HISTORICAL NOTES.

103

PART II.

MINING AND METALLURGICAL APPLIANCES
TEXTILE MACHINERY;
PAPER-MAKING AND PRINTING MACHINERY;
AGRICULTURAL IMPLEMENTS;
MACHINE TOOLS;
LIGHTING APPLIANCES;
TELEGRAPHIC APPARATUS.

Second Edition, with a Supplement containing illustrations.

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Dr. T. W. Adams
gt.
11-8-1922

PREFACE.

THIS Collection was commenced in 1867, by direction of the Lords of the Committee of Council on Education, with a view of affording in the best possible manner information and instruction on the immense variety of machinery in use in the manufactures of this country, and by the employment of which the commerce of the nation has been rapidly extended for many years past. A most valuable addition, consisting of models, made by James Watt himself or his workmen, was in 1876 presented to the Museum by Messrs. James Watt & Co. A further large accession of machines and models was received from the Patent Office Museum when, in 1884, it ceased to be continued as an independent collection, and its contents were handed over to the Science and Art Department, now merged in the Board of Education. The mining and metallurgical models from the Museum of Practical Geology in Jermyn Street, which collection was commenced in 1839, were transferred to this Museum in 1893–5.

From time to time purchases of particularly interesting objects have been made, but to a very large extent the Collection has been assisted by presents and loans of machinery, models and drawings, from manufacturers and inventors, and it must always rely mainly upon such sources for its augmentation.

It is not the object of the Collection to attempt, nor is space available, to indicate the present state of the arts in any one particular branch of engineering, but rather to illustrate broadly the steps by which advances have been made up to the present day; to show students and others at the same time the general principles which underlie all its branches and to offer to the engineer suggestions or ideas from other branches of his profession for improvements in the work on which he may be engaged.

Many of the machines are shown in motion daily from 11 a.m. till closing time, the motive power being supplied by a compressed air service. Where practicable, these working models are fitted with self-closing air-valves, by means of which visitors may start them at will, notices to this effect being placed with the models so fitted.

The more important objects in the Mechanical Engineering Collection have been photographed. Particulars of prints and lantern slides that are available may be obtained on personal application at the Sale Stall or by letter addressed to "The Secretary, Board of Education, South Kensington, S.W."

⁂ *In the Science Library of the Victoria and Albert Museum is a complete series of Specifications of the Patent Office, from A.D.* 1617 *onwards, which may be consulted free.*

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CONTENTS.

(The objects in the various sections are arranged chronologically.)

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When a reference is made in the text, it is to the serial numbers at the beginning of each entry. When an object is illustrated the reference is given immediately after the entry. The numbers on the right hand lower corner are those under which the objects are registered in the Museum, and the dates given are generally those when the objects were first received.

MINING APPLIANCES.

Deep Boring.—It is usual, before commencing more extended operations, to ascertain by borings of small diameter, the nature of the strata to be traversed, and the depth and extent of mineral deposits when reached. Two methods are used:—rotation and percussion. In the first method, in soft ground, shell or screw augers, rotated by hand or by power according to the depth, can be used. The connections to the tool, as the depth increases, are made by adding rods with screwed joints (*see* No. 1,001). The auger when full, must be drawn up, necessitating unscrewing and screwing up again the line of rods. This loss of time may be avoided by forcing down a current of water to carry up the fragments. Sometimes the lining tube is provided with a steel cutting edge and itself rotated. The most important tool, successful in the hardest

rock, is, however, the diamond drill, a shell tool, in which rough diamonds are embedded. The cores brought to the surface show the strata traversed.

In the percussive method, iron and wooden rods or ropes are used to actuate the tool. For shallow depths the rods are lifted by a winch and let fall by a trip gear; for greater depths a lever or spring beam is employed; for deep holes of large diameter a steam engine is used. In the Fauck and Raky methods rapid blows of short stroke are given (*see* No. 1006), the sludge being continuously removed. With the rope method, winding can be done at a high speed, an economy in time over a line of rods, when the sludge pump has to be lowered, which economy increases with the depth of bore.

Excavating.—Picks, shovels, hammers, and wedges are most important excavating tools and have been modified variously to suit the needs of different localities. Although space has not been found for their exhibition, a collection of such tools is available for reference. When a breaking-down agent is to be employed, boring and drilling by rotative or percussive action are resorted to. Screw augers rotated and fed by hand (*see* No. 1009–10) are commonly used in coal or moderately hard rock such as slate. The simplest percussive tool is a jumper or chisel used by its own weight or by a hammer. Its action is imitated on power-driven drills which bore two or three times faster than hand work. The working fluid in rock drills is controlled by tappet on air-driven valves, or the drill may be valveless (*see* No. 1018). Steam may be the working fluid in the open, but compressed air is used underground as it has the advantage of helping to ventilate the working place; its efficiency, however, is low, and electrically-driven drills are beginning to be employed.

Blasting and wedging (*see* Nos. 1031–5) are the chief means by which the drilled mass of rock is broken down. Gunpowder appears to have been used in mining early in the 17th century, but is now largely displaced, except when the rock is required in large blocks, by more efficient explosives which have a greater shattering action, such as the nitro-glycerine and the nitro-cellulose class.

Supports for Excavations.—Underground passages and working places, with rare exceptions, will not stand unsupported indefinitely. The character of the support that must be used varies with the nature of the ground, the material adopted, viz.: timber, masonry, or metal, and the form of the excavation, whether vertical or steeply inclined "shaft," horizontal or inclined "level," or large and irregular "chamber." Timber is most used owing to cheapness and the ease with it can be worked. Its short life, danger from fire, and great bulk for a given load are its chief defects. Stone, brick, and concrete, built dry or with cement or mortar, are used for shafts and

levels where their high first cost is more than compensated for by greater durability and low cost of upkeep. Water-tight masonry is used also in passing through water-bearing strata. Iron and steel are used for the same services and have the further advantages of small bulk and weight in proportion to strength and the possibility, in the case of steel props and caps, of use elsewhere; the advancing price of timber is leading to a greatly increased use of metal.

The form of support depends to a great extent on the nature of the pressure met with. In shafts pressure is met, in the case of timber, by rectangular sets or frames, closely spaced or with distance pieces, and having boards or poles behind when necessary to prevent loose ground falling in (*see* Nos. 1042–3). In metal, the frames are circular or the lining is of continuous cast iron segments. In levels, pressure may be met with in all directions, when a complete frame specially jointed becomes necessary (*see* No. 1060). In metal, curved frames are sometimes substituted for the usual trapezoidal shape. In working places, logs placed upon one another, two by two, crosswise, form efficient supports. The square-set timbering so largely used in the United States consists in framing timbers in rectangular cells (*see* No. 1061).

Haulage and Hoisting.—Only those appliances exclusively used in mines are included in this section; others are placed with transport and lifting machinery (*see* Catalogue, Part I.). The common method of bringing a mineral to the surface is by means of a rope winding on a drum. Many forms of power are used for actuating it (*see* Nos. 1078–86) necessitating some framework over the shaft for supporting the guide pulleys. The pit head frame is usually of timber (*see* No. 1093) but where winding operations are extensive and the structure is to be permanent, steel frames are often erected. The receptacles used for raising the materials are:—buckets or kibbles, filled at the working place and hung on the rope loosely; boxes or skips, filled from a bin fed by wagons and working in guides, used more especially in irregularly inclined shafts; guided cages—the most general system—receiving the underground wagons and lifting them to the surface. In the last case the guides are vertical and the highest speed of winding is attained; the miners also can travel in cages. Much ingenuity has been expended on safety appliances for retaining the cage should the rope break, and for disconnecting the cage should it be overwound (*see* Nos. 1095–1108). Winding ropes are made of hemp, manilla, or steel wire, the section being circular or flat.

Mine Ventilation.—The air of mines is rendered impure by dust, and more particularly by carbon dioxide given off in the breath of animals, by burning lights, by explosives, and by decaying timber; in coal mines, especially, the strata also give off gases which form explosive mixtures with air and create

serious dangers which can only be diminished by ventilation. Natural ventilation caused by the current of air produced by the difference of temperature that nearly always exist between the air of a mine and that of the external air where there are two shafts of unequal depth is the method generally relied on in vein mines. The want of constancy and of strength is a difficulty that has been met in collieries, where considerable circulation is required, by the simple and early method of heating the air by a furnace (*see* No. 1113). Artificial ventilation on the large scale, however, is always effected by mechanical means, of which the centrifugal fan is the only appliance capable of dealing with the huge volumes of air required (*see* Catalogue, Part I.).

Lighting.—Artificial illumination is a necessity at all times underground, and the means employed are candles, lamps, gas, and electric light. With the exception of safety lamps (*see* No. 1118) these do not differ from the means adopted above ground (*see* page 287).

The electric light, although generally more costly, is so superior that more work can be done with greater immunity from accident by its aid than with any other illuminant. The incandescent lamp is most generally used in main haulage roads, and in isolated cases it has been adopted for the working places.

DEEP BORING.

1001. Model of boring plant. (Scale 1 : 10.) Presented by Mons. Paulin Arrault, 1891. Plate I., No. 1. M. 2409.

This model represents a complete apparatus for boring holes of from 4 to 6 in. diam. to a depth of from 60 to 80 ft.

It consists of a tripod with tubular legs, one of which is combined with a single-purchase hand-winch, which is provided with a strap brake. The legs are connected at the top by an iron ring, through which the boring rods pass when being uncoupled. The chain from the winch passes over a pulley at the top down to a block with a swivel hook. The holes are bored by rotating augurs if the ground be soft, and by percussive chisels in hard ground or rock. For this latter process the top length of boring rod ends in an eye in which a combined hook and lever engages. This lever is attached to the hook of the lifting chain, and also catches the eye of the top boring rod, so that when the chain is wound in the rods are raised. The master-borer, who is holding the end of the lever with his right hand, and the top of the rod with his left, rotates the rods a certain amount, and then, by depressing the lever, releases them. The fall of the rods chips the bottom of the hole. The rods are again lifted by the assistant at the winch and the operation repeated. After a time the accumulation of chips necessitates the hole being cleared, which is done by withdrawing the rods and introducing a sand pump or sludger. This consists of a tube provided with a ball valve below, so that the sludge will readily enter but cannot return, and can thus be brought to the surface.

The pump is alternately lowered and withdrawn until the hole is sufficiently cleared to continue the boring. Various forms of boring tools and earth augers are shown, together with the wrenches employed for screwing up and unscrewing the boring rods and tools.

1002. Boring tools. Made by Messrs. Clinton & Owens, 1865. M. 1406.

This is an outfit of tools for boring holes, 2·5 in. diam., by percussion or rotation. It includes:—swivel head; 10-ft. boring rod; spanner; flat and T chisels; shell and screw augers; spring hook and dart; sludge pump; bell screw for broken rods; crow's-foot for recovering rods; 3-ft. length of lining tube with bayonet joint, and 3-ft. length of lining tube with steel shoe. The connections are made by screws, the thread having a greater net sectional area than the rod has. The taper between the thread and the collar reduces liability to breakage.

1003. Model of boring plant. (Scale 1 : 8.) M. 2648.

This represents a hand-power plant for deep boring by percussion with rods. The topmost rod is attached by a chain and adjustable lengthening screw to a sector head on a jumping lever carried by a low timber framing. There are three positions for the fulcrum of the lever, so that the ratio of the arms can be varied. The rods are of iron, 1·25 in. sq. and in 15 ft. lengths, with screwed socket and end. For deeper sinking wooden rods are employed. For lowering and raising the rods, a rope runs from a single geared windlass over a pulley supported by an outer framing 35 ft. high, which carries also a windlass, pulley, and lighter rope for actuating the sludge pump.

1004. Model of deep boring plant. (Scale 1 : 12.) M. 1407.

Two lined bore-holes through various strata are represented to illustrate alternative free falling arrangements when, owing to the depth of the hole, the weight of the rods becomes so great as to cause destructive vibrations. The chisel (*see* adjoining case) is held on a short heavy rod, and, after being lifted a predetermined distance, is released.

In the method introduced by Mr. C. G. Kind about 1850, the chisel is lifted by two clip hooks with sufficient play on their supporting pin to shake clear when the rod is stopped.

In the arrangement of Mr. M. J. Degousée of 1853, the lifting clips are tripped by stops on a rod which is supported from the bottom of the hole.

1005. Boring head. Constructed by Messrs. Mather & Platt, 1894. M. 2777.

This tool is used in the percussive boring system originally introduced by Mr. C. Mather in 1854.

When in use it is suspended from the flat rope shown, which is wound on a steam windlass that will quickly lift the tool for cleaning out, &c. From the drum the rope passes over a pulley carried by the piston rod of a vertical steam cylinder, so that on the upstroke of the piston the boring head is lifted a distance equal to twice this stroke; the valve gear then reverses and the tool falls and chips the bottom of the hole. To rotate the cutter so as to keep the hole circular, two crown ratchet wheels are fitted in the head and worked by teeth on the sliding collar by which the lifting rope is attached; the result is that the cutter is rotated through the space of one tooth at each double stroke. The tool is 6-in. diam. and has four chisels, but holes up to 45-in. diam. are bored in this way and cores may be cut out to show the strata traversed.

1006. Model of percussive boring plant. (Scale 1 : 10.) Presented by Messrs. Tranzl & Co., 1906. M. 3459.

This hand-plant illustrates the "rapid" rope-boring system patented in 1898 by Herr A. Fauck, in which the cutting tool is arranged to give a large number of blows of very short stroke in a given time, the sludge meanwhile being continually removed from the hole by a current of water brought down through the hollow rods. The great advantage of this is that the time usually spent in removing the sludge by withdrawing the rods and putting down a sludge pump is saved, and this saving increases with the depth of bore.

The reciprocating motion is obtained from a pulley mounted eccentrically on a shaft, on which is keyed a fly-wheel with a rim brake; this shaft is connected by gearing in the ratio 9 : 1 with a drum shaft turned by winch handles and a connecting rod. The rope or chain from which the boring rods is suspended passes over guide pulleys at the head of the boring frame and round the eccentric pulley, the end being attached to a barrel with a hand-wheel and worm gear feed. The rope is detached from this and hooked on to the drum when it is required to raise the rods.

By using toothed cutting edges and reversing the direction of the flushing current, cores can be obtained continuously without stopping work, as the vibration of the rods breaks off pieces which can be washed to the surface. A stuffing box in a cap provided with inlet holes screwed on to the top of the lining tube, as shown, then becomes necessary. With this method bores have been put down in the oil fields of Galicia to depths of 900 to 1,800 ft. at the rate of 30 to 36 ft. per diem.

The plant shown is suitable for depths up to 1,000 ft.; the stroke is 2·2 in., and the speed would be about 250 strokes per min.

1007. Tools for withdrawing lining tubes. Made by P. S. Reid, Esq., 1865. M. 1408.

These are iron rods swelled out at the end to nearly the diameter of the tube to be withdrawn and brought to a point. A spring in the swelled part keeps a toothed stud pressed against the side of the tube when lowering, and when lifting causes it to catch under the end of the tube or against a socket.

EXCAVATING.

1008. Processional axes. Received 1872. M. 1598.

Axes, such as these, are borne in procession as emblematic of their calling by the members of the miners' guilds in Saxony. They are dated between 1664 and 1749. The handles are inscribed with views of mining operations.

1009. "Peg" boring machine. Made by the Hardy Patent Pick Co., 1891. M. 1584.

This is an arrangement for using a screw auger for boring holes. A V-threaded screw 22 in. long. 1 in. diam. has at one end a handle and at other an auger; a nut on the screw is supported by the peg shown in a plank fixed at a suitable distance from the face. As the handle is turned the auger is automatically fed forwards while being rotated; the handle has two holes in it, so that when working near the roof it can be shortened. The augers are of several lengths, a short one being used to commence a hole, followed by two or three longer ones according to its depth: those shown are 24 in. and 42 in. long and bore a hole 1·5 in. diam.

The defects of this simple drill are that its forward feed is invariable and is too quick for use in any but soft rock, while it takes almost as long to screw back to put in a longer auger as to screw forwards when boring.

1010. Ratchet drill. Made by the Hardy Patent Pick Co., 1891. M. 1591.

This machine is an improved auger drill. The screw is V-threaded, 1·25 in. diam., ·143-in. pitch, and 20 in. long; the nut, patented by Mr. A. E. Stayner in 1886, is in halves which by means of a screw can be brought together. When the auger is boring the nut is closed, but when the auger is to be drawn back the halves are separated and the screw released. The screw is turned by a reciprocating handle and ratchet wheel, supported by an enclosing sleeve that bears against a wooden prop. The sleeve, to the front of which the nut is attached, is prevented from turning by a small cross-bar attached to it, and bearing against an iron spike driven into the prop. The three augers shown are 18 in., 30 in. and 42 in. long respectively, and bore holes 2 in. diam.

1011. "Elliott" drill. Made by the Hardy Patent Pick Co., 1891. M. 1585.

In this auger drill patented in 1888 by Mr. G. W. Elliott, there is a variable forward feed and a quick return. As the drill can be made small, it may be used in comparatively hard rock and thus has a wide application.

The usual nut is replaced by a worm-wheel kept in position by a brake, as in Whitworth's friction-feed drilling machine. When the brake is fully on, the screw moves forward the full extent of its pitch, but when the brake is free the worm-wheel turns idly and the feed screw when rotated, does not advance, but conversely the feed screw can without rotation be rapidly pulled back or pushed forwards; between these two extremes any amount of feed can be obtained by tightening up the worm-wheel. The feed screw is 1·625 in. diam., 27·5 in. long, and has a square thread of 0·5 in. pitch. The three augers shown are 18 in., 36 in., and 54 in. long respectively; the machine is worked by a reciprocating handle turning a ratchet wheel, and bores a hole 1·875 in. diam.

The machine is provided with an abutment or stand, made in halves, so that by shifting a pin its length can be altered to suit the height of the working place.

1012. Model of boring machine (scale 1 : 4) and food carrier. Lent by T. Hurry Riches, Esq., 1896. M. 2961.

In April 1877, 14 miners were entombed at the Tynewydd Colliery, Glamorganshire, by the inrush of water from an adjacent working; nearly all these men were ultimately rescued, several by the removal of the water by pumping. Five of the latter had taken refuge in a rise heading. An air-locked hole was made through the solid coal by a boring machine, represented by the model, and food in a liquid form supplied to them in pointed canisters provided with supporting wheels, as seen in the specimen preserved. The boring machine was a hand-worked geared tubular drill with a screw feed. Both it and the carriers were designed and made by Mr. Riches.

1013. Model of hand power rock drill. (Scale 1 : 3.) Constructed by Messrs. T. B. Jordan & Sons. M. 2820.

This is a later form of a drilling machine patented by Messrs. T. B. Jordan & J. Darlington in 1866; it is driven by hand-worked winch handles, but the blow is delivered by an air spring.

A frame with four adjustable legs carries two hand fly-wheels and a vertical cylinder; the cylinder is fitted with an air-tight piston and a long hollow piston rod, through which passes a feeding screw connected with the

drill. By a shoulder on the upper end of the piston rod the screw is lifted by a cam on the fly-wheel shaft, so compressing the air above the piston and at the same time rotating the drill by an inclined toothed ring. When at the top of the travel the cam leaves the lifting collar, and allows the piston and drill to spring forward under the action of the compressed air. The feeding is performed by a hand wheel and bevel gear, that rotates a nut on the feed screw. In a later arrangement the machine was much simplified and the feed was given by a toggle grip that allowed the long drill to creep forward while at work.

1014. Model of "Ingersoll" hand-power rock drill. (Scale 1 : 2.) Lent by Messrs. Clark & Wellington, 1887. M. 1867.

In this machine, as the fly-wheel handle is turned the drill is lifted by cranks and a strong helical spring is compressed; as soon as the cranks have passed the top centre the spring drives the drill down rapidly, the cranks running freely forward under the action of the spring owing to the crank shaft being able to overrun the fly-wheel, through there being only a ratchet-wheel connection. The drill is turned automatically by means of a rifled bar, round which the spring is coiled and which rotates it during the up stroke. The feed is given automatically or by hand; in the former case a swelling on the drill bar acts as a tappet to strike a lever which, by means of a pawl, rotates a ratchet wheel arranged just below the handle which is used when feeding by hand.

1015. Portions of early rock drill. Presented by G. Green, Esq., 1902. Model (scale 1 : 8) made in the Museum, 1903. Plate I., No. 2. M. 3245.

This example of a percussive rock drill, to be driven by compressed air or steam, was made in 1863 by Mr. G. Green, under the patents of Mr. E. S. Crease, and used at the Clogau Mines, North Wales; it is believed to have been the first machine of the class to be practically worked in this country. It was favourably mentioned by the Royal Commission on Mining in 1864; but owing to there being no air-compressing machinery available at that date, steam was used as the motive power, and this restricted the employment of the drill to short or open workings.

The machine consists of a cylinder having a piston and rod carrying the boring tool, while at the end of the piston rod are two tappet collars which actuate the valve and also the gear for feeding and turning the tool. A forked lever, whose upper ends engage with these collars, is pivoted to an arm on the cylinder and drives the valve from its lower end, while from another point in it the turning and feed gears are driven by means of rods and levers. The turning is performed by a ratchet wheel, which rotates a spindle passing through the cylinder cover and into the piston rod, where there is a feather connection. The cylinder is carried in slides, containing a nut through which passes a feed screw, secured to the cylinder and rotated by change wheels from the ratchet-wheel above.

To enable holes to be drilled in any position or direction the cylinder slides are attached, by a swivel connection, to the end of a sliding bar, which passes through a sliding socket embracing a vertical pillar. This pillar is carried on a four-wheeled iron truck and has a swivel-headed screw at its upper end for strutting the machine from the roof; rack and pinion gear is, moreover, provided for raising the socket up the pillar.

The cylinder is 4·25 ins. diam. by 4 ins. stroke, and with a steam pressure of 15 lbs. per sq. in. the drill delivered 400 to 500 blows per min.; it is stated that in average rock the holes were drilled at the rate of 1·5 in. per min. The portions shown of the actual machine are the cylinder, slide, and sliding bar with its socket; the model represents the complete machine, which weighed about 15 cwts.

1016. "Barrow" rock drill. Made by Messrs. M. Loam & Son, 1894. M. 2655.

This is a full size model in wood of an early successful drill for working by steam or compressed air; it was patented in 1874 by Mr. R. Hosking and W. Blakewell. The machine consists of a cylinder fitted with a long double piston, to the projecting rod of which the bit is attached. Centrally in the piston is a spherical swelling, which acts as a tappet to oscillate a double slide valve capable of turning on a central pin. The rotation of the drill is performed by hand, through a central spindle which fits a hole in the piston, and by means of a feather transmits the rotation without interfering with the free reciprocation of the piston.

The cylinder is carried in a slide attached by swivel connections to a support, usually formed of an extensible strut which can be fixed across the level. Between the guides is secured a nut, in which works a screw connected by gearing to the hand shaft, so that the movement that rotates the drill also advances it.

1017. "Eclipse" rock drill. Presented by Messrs. Hathorn & Co., 1885. M. 1628.

In this machine the distributing valve is of the pressure-moved type. The drill is clamped into the piston rod of a small direct-acting cylinder, and to the cylinder is bolted a small valve box containing a piston valve. The main piston is long, and when at the extremities of its stroke, opens communication alternately with opposite ends of the piston valve, and in this way the motion of the piston moves the slide valve so as to cause the reverse motion, the action being so quick that several hundred blows per minute are regularly delivered. The simultaneous rotation of the drill is secured by a rifled bar working in a nut in the piston and controlled by a ratchet wheel at the cylinder end. The cylinder is carried in a cradle, fitted with a double swivel and three adjustable legs so that the drill may be pointed in any direction, while a screw fixed to the cradle and engaging in the nut on the cylinder enables the drill to be fed forward by hand. The cylinder nut, however, is provided with ratchet teeth, into which a pawl driven by a vertical rod that receives motion directly from the piston engages, and so automatically feeds forward the whole cylinder.

1018. Diagram models of the "Adelaide" rock drill. (Scale 1 : 4.) Presented by R. E. Commans, Esq., 1891. M. 1587.

These represent in section the cylinders of what is known as a "valveless" drill, the piston by its motion distributing the working fluid; the drill was patented in 1881–2 by Mr. G. F. Wynne.

The air is always at full pressure in the annular port at the front end of the cylinder. When the piston is moving forwards, air is being admitted to the back of the piston through a hole in the hollow piston rod; the air is soon cut off by the hole being covered, and the remainder of the stroke is completed by expansion. Exhaust takes place at the front end through the hole formerly admitting air, and also through the exhaust hole in the hinder part of the cylinder. Simultaneously air is admitted to the front of the piston through a broad hole cut in the piston. The turning is done automatically by a rifled bar and ratchet-wheel, but the feed is by hand.

1019. Franke's mechanical chisel. Made by Messrs. Friemann & Wolf, 1894. M. 2555–6.

This is a percussive machine, patented in 1890 by C. Franke, for under-cutting in rock. It performs its work by striking some thousands of light blows per minute, under the action of compressed air conveyed by a flexible

pipe, and, as it can be held in the hand, it is exceedingly portable. The inertia of the machine at this high speed appears to prevent any reaction being felt by the miner.

It consists of a steel barrel fitted at the front end with a tool holder, which is forced backwards by a spring. In the barrel is also a plunger that is forced to and fro by the compressed air, and at the extremity of the forward stroke strikes the tool holder by which the blow is transmitted to the chisel edge. The air is distributed, and cut off so as to act expansively, by a small slide valve in the form of a ring which fits in a recess in the plunger. The exhaust takes place through the centre of the plunger and the slide valve, which is worked by air pressure, places one end of the plunger in communication with the air supply, and the other with the exhaust, the resulting motion of the plunger carrying the valve to the other side of the air supply port, and so causing a movement of the slide which reverses the action. Air at 60 lbs. pressure is used, and the stroke of the chisel is ·06 to ·08 in.; the chisel is of ·5 in. round steel; the machine weighs 10 lbs., and can undercut to a depth of 2 feet.

Another specimen of this machine is shown in which, by a rifled bar arrangement, the tool holder is rotated as the reciprocation proceeds, so that holes may be drilled.

1020. Model of "Optimus" rock drill. (Scale 1:4.) Presented by Messrs. R. Schram & Co., 1893. M. 1586.

This represents in section the cylinder and valve of a drill patented by Mr. P. J. Ogle in 1891. The drill is driven by steam or compressed air, and works as a compound engine; the fluid first acts on the back of the piston driving it forward, and then the same charge, acting on the front, performs the return stroke. The piston is a double one of two different diameters, and the space between the two portions is always open to exhaust; the front portion is the larger. The valve is on the side of the cylinder, and is moved by the working fluid. During the forward stroke, air is acting behind the small piston, while the rest of the chambers are free to exhaust; but, when the limit of the stroke is reached, the small piston uncovers a port that admits air that moves the slide valve. The slide valve, after cutting off the supply to the piston, opens a passage from the small cylinder to the front end of the big one; the air then acts on a larger area, and so drives the piston backwards while expanding. The rotation of the drill is performed by the usual rifled bar and ratchet wheel; the feed is given by hand.

1021. "Daw" rock drill. Lent by Messrs. A. & Z. Daw, 1898. M. 3022.

This is an air or steam worked percussive drill, patented originally in 1887 by Messrs. A. W. & Z. W. Daw, in which the external distributing valve is moved by the working fluid.

The piston is of exceptional length and has a recess around it that is always in communication with the fluid supply pipe. When the piston reaches either end of its stroke, this recess admits the working fluid into ports that convey it to the ends of the external slide valve, which is of the piston type; in this way the piston on reaching the end of its travel causes the slide valve to move in the direction necessary to insure the return stroke of the piston. The rotation of the drill is given by the usual rifled bar and ratchet wheel, while the feeding is performed by a hand-worked screw (*see* sectional drawing).

The cylinder carriage is provided with a swivel head which is clamped to a sleeve that fits on a bearing formed on the head of a tripod; by this means the drill can be set to work in any direction. In the support shown the legs are fitted with heavy weights, as usual when quarry working.

1022. Model of portable rock drill. (Scale 1 : 8.) Made by the Ingersoll-Sergeant Drill Co., 1904, Plate I., No. 3. M. 3316.

This is a percussive rock drill to be driven by steam or compressed air, and is a development by Mr. H. C. Sergeant of a drill invented by Mr. S. Ingersoll in 1872.

The chisel is clamped into the end of the piston rod of a direct-acting cylinder, to which is bolted a valve box containing a pressure-moved distributing valve, actuated by differences in pressure, caused by an auxiliary tappet valve moved by the piston. The cylinder ends are retained in position by two long tie rods acting through plate springs which serve as buffers when the stroke is excessive. The rotation of the drill is secured by a rifled bar, engaging with a nut in the piston and controlled by a rachet ring at the cylinder head; this ratchet ring is, however, only retained by the pressure of the buffer springs and will slip when excessive resistance to turning is encountered. The drill cylinder is 3 in. diam. by 6·5 in. stroke and, with a pressure of 60 lbs. per sq. in. gives about 350 uncushioned blows per min. It drills holes from 1·5 to 2·25 in. diam. up to 14 ft. deep, the average work in granite for vertical holes being 70 ft. in 10 hours.

The cylinder is carried by a cradle in which it slides when the feed screw is worked by the attendant, and the whole drill is attached to a tripod by a universal joint so that it may operate in any direction. The tripod has weighted telescopic legs, two of which are provided with universal joints, but when working in underground headings the drill is generally mounted on a single column, which is shown detached.

1023. Model of quarry bar rock drill. (Scale 1 : 8.) Made by the Ingersoll-Sergeant Drill Co., 1904. M. 3317.

This consists of an ordinary rock drill mounted on a long bar supported by four legs. It is for use in quarries where straight rows of holes are required, for breaking rock, or for broach channelling in granite or other rock too hard for a channelling machine.

The bar is a hollow cylinder, provided with a rack along its upper part and a feather along the lower surface. It is attached by clamps to two cross-heads having at their ends swivelling sockets for securing the supporting adjustable legs, which are weighted. The drill is attached, by a universal joint, to a sliding sleeve which may be placed at any part of the bar, and the sleeve can be traversed along the bar by hand through a pinion gearing with the rack.

The bar is 4·5 in. diam. and 12 ft. long. The drill represented is described in No. 1022. The total weight of the machine is 1,730 lbs.

1024. Model of bar channeller. (Scale 1 : 8.) Made by the Ingersoll-Sergeant Drill Co., 1904. Plate I., No. 4. M. 3318.

This machine is for cutting deep grooves in rock, preparatory to removing the stone in blocks by wedging or blasting, and is a combination of a rock drill with a special form of portable double bar frame, patented in 1889 by Mr. H. C. Sergeant.

The frame consists of two cylindrical guide bars connected at the ends by trunnion pieces, which are carried in crossheads having at their ends swivelling sockets for receiving two adjustable legs. These legs, which are provided with steel points and lifting sockets, are held down by removable weights. The drill cylinder is mounted in a cradle, down which it is fed, as required, by hand, and the end of the piston rod is attached to a guided crosshead carrying a gang of chisels. The cradle is secured to a saddle fitting the guide bars and traversed along them by a small three-cylinder engine, which rotates a nut engaging with a stationary screw parallel with the bars, This traversing motion is automatically reversed at the ends of the travel, and it has a friction drive which slips under any excessive stresses.

Work is commenced by drilling a circular clearing hole at each end of the intended groove. The drill chisel is then removed, and a gang, or group of chisels in one plane, substituted, by which the groove is gradually chipped out as the cradle moves to and fro along the guide bars. Owing to the guide bar crossheads being carried in trunnions, the machine can be set at any desired inclination.

The drill represented is described in No. 1022. The travel of the machine s 8 ft., and it is designed for cutting channels to a depth of 7 ft. The working capacity is from 60 to 100 sq. ft. per day, and the weight of the complete machine is about 3,000 lbs.

1025. Model of travelling channelling machine. (Scale 1 : 8.)
Made by the Ingersoll-Sergeant Drill Co., 1904. M. 3319.

This machine, for cutting vertical channels in rock, was introduced in 1893 and extensively employed for cutting the sides of the rock excavations of the Chicago drainage canal. It consists of a large percussive drill, mounted on a self-propelled four-wheeled truck carrying its own boiler and running on a portable railway. The steam to the drill piston is distributed by a pressure-moved piston valve, whose motion is determined by an auxiliary valve moved by a tail-rod. The cylinder, with a crosshead to which is clamped a gang of chisels in one plane, is carried in a cradle bolted to a vertical plate firmly attached to the truck. The drill overhangs the side of the truck, and is fed downward by a screw rotated by a small three-cylinder engine. The whole machine is moved to and fro along the track, as the gang of chisels are chipping away the rock, by means of another three-cylinder engine, which drives the axles by worm gearing and a friction clutch so as to prevent damage should excessive resistance be encountered.

The boiler is vertical, and, in addition to being bolted to the truck, is guyed by elastic stays. The steam connections to the drill cylinder are made by telescopic and swivelling pipes which permit of the drill being placed in any position on the vertical plate.

The machine usually cuts channels from 4 to 7 ft. deep, and from 30 to 50 ft. long, but the depth may be increased to 14 ft. The gauge of the track is 4·8 ft. outside, and the weight of the machine is about 9,000 lbs. (4·25 tons).

1026. Models of circular coal-cutting machines. (Scale 1 : 4.)
Contributed by C. H. Waring, Esq., 1875. M. 1375.

These machines were patented by Mr. Waring in 1852 "for cutting coal, shale, &c. in coal pits." Although they did not come largely into use, similar machines driven by compressed air have since been employed with considerable advantage in working thin seams.

In the first machine a thin horizontal wheel with four projecting double teeth is rotated by bevel gear driven by two men who, by hand levers and connecting rods, drive two cranks at right angles. The axis of the cutting wheel is carried on a frame that slides in guides on a trolley that can be lifted off its wheels by four screwed legs. The frame, carrying with it the disc, is automatically forced forward along the guides by rack and pinion, driven by worm gear from the main shaft.

In the second machine, two saws are arranged on a horizontal axis, so that they make two vertical cuts such as would be necessary for the sides of a level. The axle of the saws is mounted in a frame that can be elevated while at work, and this frame is carried in slides on a four-wheeled carriage. The saws are rotated at considerable speed by gearing, driven by two men at reciprocating handles as before, while the frame is automatically advanced along the slides by a ratchet feed. The trolley wheels are mounted in forks and can be swung round so as to resist running back.

1027. Model of reciprocating coal-cutting machine. (Scale 1 : 4.) Contributed by C. H. Waring, Esq., 1875. M. 1375.

This machine, patented by Mr. Waring in 1852, cuts a single chase in the working face of the coal, in either a vertical or inclined direction, by means of teeth or cutters attached to the front edge of a thin metal frame which, by a crank motion, is rapidly reciprocated on two circular guide rods attached to the machine, and provided with pointed extension screws by which they can be secured to the sides of the working. The frame holding the cutters is carried in slides on the frame that receives the reciprocating motion, and is advanced by feed screws that are automatically turned with each reciprocation. The machine is mounted on horizontal trunnions carried on a four-wheeled trolley, and is driven by one or two men working at a winch handle. There are two winch shafts so that the men may work either at the side or behind the machine. A weighted fly-wheel counterbalances the weight of the reciprocating frame, and also steadies the motion.

1028. Coal-cutting machine. Presented by Robert Ridley, Esq., 1864. M. 1395.

This machine, patented by Messrs. R. Ridley & J. G. Jones in 1863, was used with considerable success at the Ardsley Colliery, Leeds, and at the Newbottle Colliery, Sunderland. It is driven by compressed air, and swings horizontally a pick which undercuts the coal, while the machine is moved on rollers along the working face.

The machine consists of a metal frame, carried on four flanged wheels, which are geared together and rotated by a horizontal handwheel at the top, so as to travel it along while the undercutting is being performed. Within the frame is a horizontal cylinder fitted with a piston and trunk. By a connecting rod the piston rocks an arm attached to a vertical shaft, which is provided below with a socket that carries the pick. The air supply of the cylinder is distributed by a slide valve worked by a tappet motion. A second vertical shaft and pick socket are provided, so that the machine can be worked either right or left handed.

It is stated that this machine was capable of undercutting a seam of coal to the depth of 3 ft. and to the length of 150 yds. in eight hours. The air was supplied at a pressure of 50 lbs. and delivered to the machine through india-rubber tubing 1·25 in. diam.

1029. Bar coal cutter. Presented by Messrs. Mavor & Coulson, Ltd., 1906. M. 3259.

The bar type of mechanical coal cutter was tried as early as 1856 by Messrs. W. O. Johnston & J. Dixon, of Newcastle, who employed a revolving tapered bar provided with four helical grooves in which were inserted chilled cast-iron cutting tools. The arrangement was subsequently developed by others, including the firm of Mr. W. T. Goolden, who were among the first to employ an electric motor for driving the cutter bar—a duty for which it is particularly suited owing to the speed of the bar being high.

The bar shown, which was patented by Messrs. F. W. Hurd and J. J. Millar in 1895, is tapered and has a square thread cut along it; at the top and bottom of the thread, to suit the depth of chase to be cut, are tapered holes into which are inserted steel picks, the cutting portion of which is inclined to the shank at an obtuse angle. The thread acts as a conveyor in bringing out the cuttings, thereby preventing the coal from being so well supported by the fragments as to interfere with its being broken away from the top, in which case the work would have to be done over again by hand.

In addition to rotating, the bar receives an axial reciprocating motion of about 2 in. from two links actuated by eccentric pins in worm wheels, gearing with a worm on the driving pinion. The bar can be moved round

in the horizontal plane by gearing, so as to cut its entrance into the coal face, and it can be used at either side; it can also be tilted, to suit the dip of a seam or to avoid obstructions, and will work at different heights above the floor as required when the seam has a dirt-parting in it. The machine, and with it the bar, are advanced by a steel wire rope made fast to a distant point and wound on a drum operated by a worm on the motor shaft, gearing into a worm wheel driving an adjustable ratchet feed.

The bar shown is from the smallest size machine, which weighs 2,128 lbs., while its bar weighs 168 lbs. The depth of the under-cut is 2·5 to 3·5 ft., and the bar runs at from 300 to 500 revs. per min.; it requires a motor of 12 brake H.P. usually supplied with continuous current at 400 volts.

1030. Wire saw for quarrying stone. Presented by Prof. C. Le Neve Foster, 1896. M. 1583.

This kind of saw has been successfully in use since about 1888 at marble quarries in Belgium and elsewhere, both for cutting blocks out of the solid, and also for cutting large blocks into smaller ones.

An endless wire rope of three strands is carried round pulleys which keep it pressed against the rock to be cut, and being fed with sand and water it abrades the material over which it is drawn. In cutting out of the solid it is generally necessary to sink two pits, one at each end of the cut; the necessary pulleys are placed on a frame in the pits and lowered by a screw arrangement as the cut deepens. In marble the speed of the wires is 13 ft. per min. and the depth cut 3–4 in. per hour. Specimens of new and worn strands are shown.

1031. Boring and wedging apparatus. Received 1872. Plate I., No. 6. M. 2647.

This apparatus, patented by Messrs. J. G. Jones and S. P. Bidder in 1868, was introduced as a substitute for explosives in coal mines; it consists of a boring auger and of an arrangement of a hydraulic jack for forcing a wedge into the hole made by the former.

The auger has a three-pointed cutting bit, bores a hole 3 in. diam., and is 44 in. long over all; it is rotated by a crank and gearing, and advanced by a feeding screw with a split nut which permits the screw to be withdrawn quickly. The whole apparatus is supported on a stand which is clamped by screws between roof and floor. The wedge is formed as a cylindrical plug, made up of two side pieces, which are forced into the hole together; a central wedge is then placed in position between them by an attached handle, which is then screwed out and the central wedge forced home by a hydraulic jack that obtains its abutment from tail rods from the side pieces.

1032. "Multiple" wedge. Made by the Hardy Patent Pick Co., 1891. M. 1588.

This improved form of the "plug and feathers," for use in place of explosives, was originally patented in 1877 by Mr. G. W. Elliott. The two side feathers are placed in the hole, then the two side wedges, and finally the central wedge which is driven in by means of a sledge-hammer. Coal, previously undercut is thus forced down.

1033. Model of mechanical coal getter. (Scale 1 : 8.) M. 1589.

This coal-getter was patented in 1883 by Messrs. W. F. Hall and W. Low and used at the Haswell Colliery, Durham. It is a compound wedge, in which the central wedge is driven forwards by a double toggle joint. The

two feathers are first placed in the hole, then the central wedge and the rod connecting it with the toggle joints is placed in position. The toggles are screwed together by turning the handle, and so the wedge is forced between the feathers with increasing force.

1034. Burnett's coal wedge. Presented by the Royal Commission on Accidents in Mines, 1886. M. 2821.

This is an example in wood of the wedge patented by Mr. C. Burnett in 1884–5. It consists essentially of rollers between the wedge and the feathers to replace sliding by rolling friction and thereby increase the bursting action obtainable.

The feathers extend backwards and are connected by a collar that forms the sleeve for a nut, which is turned by a ratchet wheel and hand lever. In the nut is a long screwed rod that terminates in the wedge. Between the wedge and the feathers is a loose box holding four small rollers; the nut, when turned, separates the feathers and so breaks down the coal.

1035. Apparatus for blasting by lime. Made by Messrs. Cort & Paul. M. 1396.

The slaking of lime and its consequent increase in volume is utilised in this method, patented in 1881 by Messrs. C. S. Smith and T. Moore, for breaking down hard coal in which there are no fissures. It was introduced at Shipley Colliery, but is no longer used.

The cartridge is filled with compressed ground lime, and is 2·5 in. diam. by 4 in. long, with a longitudinal groove along it to accommodate a perforated iron pipe previously inserted in the hole, which would be about 2·75 in. diam. by 3 ft. deep. The cartridge is tamped in with at least 9 in. of clay. A tap on the outer end of the pipe is connected by a flexible pipe with the force pump shown. When the pipe is filled with water the tap is shut and the lime does its work in 10 to 40 min. The cartridges must be kept in the air-tight case shown.

An auger on a stand suitable for preparing the holes is shown; it is a ratchet drill (*see* No. 1010), but has a solid nut. The thread is square ·166 in. pitch; the augers are 24 in. and 39 in. long by 3 in. diam.

1036. Pneumatic igniter. Made by Mons. G. J. A. E. Bourdoncle, 1892. M. 2635.

This igniter has a cylinder with an air-tight piston working in it; the fuse, together with a piece of German tinder, is introduced through the bottom end of the cylinder, a tight joint being made by an india-rubber washer. The piston is then smartly pushed home, so compressing the enclosed air that its temperature rises sufficiently to light the tinder, which in turn lights the fuse. A bell-shaped foot permits the igniter to be rested on a support while the piston is being pushed home, a side notch in its rim preventing damage to the fuse.

1037. Heath & Frost's lamp. Presented by H.M. Home Office, 1901. M. 3154.

This is an oil lamp of the bonneted Mueseler type, embodying the shot-firing arrangement patented in 1886 by Messrs. J. Heath and W. Frost. The safety fuse is inserted through the base into a tube extending into a gauze-protected space at the top; a pricker can be passed through the tube to pierce the fuse by forcing up a spring shield, and after being made red hot in the flame can be withdrawn, so igniting the fuse. It has a screw lock, and weighs 3·5 lbs.

1038. Percussion igniter. Made by Trevis Holmes, Esq., 1892. M. 2634.

In this appliance, patented in 1891 by Mr. Holmes, the end of the fuse is held in a tube containing a chamber in which is a percussion cap on a nipple. A pin which passes out of the chamber above the cap is struck by a hammer when the fuse is to be fired. A later and more convenient form of this igniter is mounted like a pistol with a percussion lock.

1039. Electric igniter. Made by W. Ladd, Esq., 1893. M. 2650.

This is a small magneto-electric machine for firing shots in mines. Four bobbins, wound with copper wire and mounted on a frame, are rotated by gearing between the poles of two compound permanent horseshoe magnets. Terminal screws are provided for the attachment of wires leading to the charge; the push-button enables the circuit to be closed at any desired moment.

1040. Apparatus for testing mining explosives (Scale 1 : 24.) Presented by H.M. Home Office, 1901. M. 3145.

A Government Committee having been appointed to determine the suitability of various explosives for use in mines, the plant represented was erected at Woolwich in 1897 for carrying out experiments by firing charges of each explosive into mixtures of air and gas, or of air and coal dust.

The plant for testing in a mixture of air and gas consists of a cannon mounted on rails and arranged to discharge into a long metal cylinder which contains an explosive atmosphere, prepared by introducing a definite volume of coal gas from a gas holder and then mixing this with the air in the chamber and pipes by a centrifugal fan, arranged in the circuit and driven by a gas engine. Suitable valves are introduced for controlling the various operations, and the explosion chamber is fitted with external flap valves and is closed at one end by a paper diaphragm, beyond which is a tuft of gun-cotton to definitely indicate if the mixed atmosphere has exploded. The cannon in which the blasting charge is fired, having to resist a pressure of possibly 100 tons per sq. in., is wire-wound and has a removable liner, as it was found that the inner tube required renewal after 200 charges had been fired. The observers are protected against any failure of the cannon, by a concrete shield at the side, and the firing is done electrically.

The charges used are equivalent to 6 oz. of gunpowder, or 2 oz. of dynamite, and the cannon is stemmed with 6 in. of dry clay; it was decided that an explosive was not suitable for use in mines if 40 charges of it fired in this way, successively, into an explosive atmosphere caused more than two ignitions of the gaseous mixture. All explosives are too dangerous to be fired without stemming, so that the dry clay stemming adopted is the least favourable practical condition; it was moreover found that the explosive atmosphere prepared was as dangerous as any possible in a mine, and more so than one of coal dust and air, while the action of the cannon represents that of a blown-out shot and was, therefore, particularly likely to fire the artificial mine gas.

The plant for testing the action of explosives in an atmosphere charged with coal dust consists of a vertical cylinder secured to a bed of concrete, in the centre of which is placed a vertical cannon, identical in construction with that in the other apparatus. The dust-laden atmosphere is blown into the base of the cylinder by a centrifugal fan, upon the delivery pipe of which is fixed a closed hopper containing coal dust. When the fan is driven by the gas engine, the air delivered into the cylinder carries with it a large amount of this coal dust, thus creating an exceedingly dense atmosphere which, however, although distinctly explosive, was found to be far less so than the explosive gaseous mixture used in the other apparatus.

SUPPORTS FOR EXCAVATIONS.

1041. Model of timber drum for shaft sinking. (Scale 1 : 12.) Made by Herr Carl Schumann. M. 2802.

This is an arrangement used when sinking a shaft through quicksand or similar material.

The frames ("curbs" or "cribs") are composed of two thicknesses of segments cut from planking, breaking joint and fixed together with wooden pegs. These are placed from 1 to 3 ft. apart, according to the nature of the ground, and a close lining of planks is nailed outside them, the edges of the planks being planed to insure a good joint; a similar lining is nailed to the inside of the curbs in the lower part of the drum so as to offer a smooth surface to the incoming skip, &c. The material inside is excavated, and the drum then sinks by its weight or is forced downwards. The lower or cutting edge of the drum is usually shod with iron as shown.

1042. Models of Cornish timbering for a rectangular shaft. (Scale 1 : 12.) Received 1883. M. 2792–3.

The frames are composed of two side-pieces halved at each end and resting upon two end-pieces, also halved; these frames are placed from 2 to 4 ft. apart, the distance being maintained by small props. A lagging of planks is placed behind the frames to keep loose material out of the shaft. In loose ground the side pressure is sufficient to grip and support the timbering, but in harder ground the frames are supported where necessary by putting in bearers, which project about 2 ft. into holes cut in each side of the shaft. In hard rock frames are often dispensed with, cross-pieces wedged against the sides being used where necessary to hold the guides.

In the first model a compartment that serves for winding the ore is cut off by means of a closed partition nailed to cross-pieces. One portion of the remaining space serves for the pump-rods and pipes; in the other part are fixed the climbing ladders, at an angle of 6 deg., resting on platforms at every 20 ft. By arranging the ladders parallel to one another they could have been placed at a much more convenient angle than that here shown.

In very loose ground it is necessary to sling the frames from one another, and from bearers at the surface or in firm ground, by means of two bolts through each end piece, as shown in the second model.

1043. Model of shaft timbering used in Saxony. (Scale 1 : 16.) M. 2804.

The model shows a small shaft 8 ft. by 6·3 ft., which might be a prospecting shaft or an underground sinking from a level.

Round timber is used, otherwise the system of support is similar to that in vogue in Cornwall and elsewhere. Bearers are put under the end pieces of alternate frames and the intermediate frames are supported from those immediately below, each by six studdles. The shaft is divided into two compartments, one for a ladder-way and the other for raising the ore in buckets. The passage of the latter up the shaft, which is often an inclined one, is facilitated by fixing planks on the foot-wall side.

1044. Model of brickwork lining for a shaft, as used in Saxony. (Scale 1 : 16.) M. 2801.

While sinking, the shaft is supported at intervals by wooden "curbs" with a backing of laths; brickwork is afterwards built in between the curbs.

The curbs are made of segments of planking pegged together, with iron clamps across the joints. The topmost curb is stronger than those below, and would be firmly supported by a ledge of ground or rock left under it.

The curbs are supported temporarly on beams slung by iron rods from the stronger curb above, the spaces between the curbs are bricked in one after another, downwards. The curbs may be left in, but it is more usual, as in the model of La Grange shaft (*see* No. 1050), to put in a brick lining throughout the shaft, the wood supports being taken out and replaced by brickwork or, if this cannot be done, the permanent lining is carried up within the woodwork.

1045. Model of shaft timbering used in Australia. (Scale 1 : 6.) M. 2810.

There is a continuous lining of thick planks, similar in many respects to that in use in the Scotch coal-fields. The side-pieces bear on the ends of the end-pieces, and the end-pieces are prevented from being thrust inward by pegs fixed in the side-pieces. The shaft is divided into two parts by planks cut long so that they may wedge into position and act as struts; they are kept from slipping sideways by boards nailed up each side.

1046. Model of shaft timbering used in the Harz. (Scale 1 : 16.) M. 2800.

The model represents an inclined shaft 30 ft. long by 10 ft. wide following the course of a lode. Rectangular sets of round timber, 12 in. diam., are first put in; the joint between the end and side pieces has bearing faces slightly tapering downwards, the end-pieces with slightly bevelled ends being wedged between. The sets are kept 3·3 ft. apart by struts.

The sets are assisted in supporting the hanging-wall by three frames within them, one at each end and one at the middle in vertical planes at right angles to the hanging-wall. When putting in one of these, a bearer 24 in. diam. is firmly fixed by hitching it in the foot-wall and wedging it against the hanging wall. Two long pieces 19 in. diam., are placed on this bearer and kept apart by struts of timber 16 in. diam., which are put in, beginning at the bottom, by cutting a socket on the foot-wall piece for one end of the first strut and hollowing its other end for wedging against the hanging-wall piece. The remaining struts are hollowed at both ends and are wedged in one after the other, each strut at one end touching the one below and at the other end being itself touched by the one above.

The shaft is divided by the middle frame into two parts, one being used for winding ore and the other for a ladder-way, pumps and often a man engine.

1047. Model of shaft timbering on the Comstock. (Scale 1 : 12.) Received 1883. M. 2795.

This timbering was first used on the Comstock lode, Nevada, U.S.A.

Square timber of uniform size is used for the frames, and all the joints are carefully made; the side-pieces of the frames are halved and rest on the end pieces. Three partition timbers notched into them serve to support the wooden guides of the cages in the three winding compartments; the fourth compartment is used for pumping. Between each two sets there are ten posts, of which those at the four corners are of extra size; the ends of the posts are notched in and the lining is completed by a close sheathing of planks.

1048. Model of shaft-sinking arrangements. (Scale 1 : 10.) Made by Mons. P. Regnard. Received 1899. M. 3044.

This shows a method of sinking a shaft through loose water-bearing strata. A pit of the usual rectangular form is excavated, and timbered with sets, studdles and plank lagging. A circular wooden curb (in this case provided with a cutting shoe) is placed on a level bed at the bottom of the excavation and brick walling built upon it to a height of from 3 to 6 ft.,

then another curb is laid, and so on. This weight, or an added load, causes the shoe to sink as the interior earth is excavated. The curbs are tied to each other and to the cutting shoe by through bolts, which are left in the brickwork. A close lagging of planks, or a mantle of sheet iron as in this model, is fixed outside the curbs to facilitate descent and prevent disturbance of the brickwork.

1049. Model of cast-iron tubbing. (Scale 1 : 12.) Contributed by Messrs. Thornewill & Warham, 1859. M. 2788.

Such tubbing is generally used in this country for water-bearing strata. As in La Grange shaft (*see* No. 1050), the segments are built upon a foundation of wedging curbs; the plates, however, are not bolted together, and the strengthening flanges, ribs, and brackets are turned towards the rock. A joint is made by strips of soft wood placed so that the grain lies radially with regard to the shaft, wedges being afterwards driven into this to make the joint quite stanch; two adjacent sides of each segment are provided with secondary flanges which overlap the joints and keep the wooden strips in position. A hole in the middle of each segment allows water to escape from the back while the plates are being laid, but is afterwards plugged simultaneously with the wedging of the joint.

1050. Model of cast-iron tubbing and details of shaft and cage. (Scale 1 : 5.) Received 1893. Plate I., No. 5. M. 2522.

This is a model of La Grange shaft, Mines d'Anzin, France, which was sunk through water-bearing strata of Tertiary and upper Cretaceous age down to the coal measures below, which were, however, dry owing to a water-tight bed at the bottom of the chalk marl. The tubbing was carried down to the water-tight bed above the coal where a joint was made, so saving a heavy constant charge for pumping. The sections of the strata on the sides of the shaft have been modelled and painted to represent the actual rock.

The lower part of the lining is of ordinary shaft brickwork, and above it are laid two oak curbs which support two strong cast-iron wedging curbs bolted together in segments; these curbs form the base upon which the tubbing is built up. The water-tight joint between them and the marl is made by a packing of moss and planks driven tight with pointed wedges.

The tubbing is formed of cast iron segments bolted together and breaking joint vertically; the joints are made with sheet lead. Across the centre of the shaft are steel girders, resting on lugs cast on the tubbing, which serve to support the steel guides for the two cages. There are four guides, supported by clamps which rest on the cross girders, a full size detail of which is shown adjacent. In addition, there are four vertical wooden rails to receive the grip of the safety catches. A close casing of boards or "brattice" on the left-hand side cuts off a segment of the shaft which is used for ventilation, while a similar space on the right is used as a ladder-way and is provided with wooden ladders and platforms at intervals.

The cages have two decks, each of which carries four wagons; safety catches worked by springs are provided so that if the rope should break the catches immediately grip the wooden guides, and retain the cage. Disconnecting hooks are also employed which in case of overwinding will release the winding rope, but support the cage at the pit-head frame. Flat winding ropes of aloe fibre are used.

1051. Models of level timbering used in the Harz. (Scale 1 : 16.) Received 1859. M. 2798–9.

The first model shows methods used where the level is driven along a vein in which one or both walls form convenient sides to the level and need but little support. When not vertical the overhanging side of the

vein is known as the "hanging-wall" and the other side as the "foot-wall." The timber cross-piece is footed in a hitch, either in the foot-wall itself or in a piece of timber lying against the foot-wall, while the other end is wedged against the hanging-wall or a piece of timber lying against it; in the latter case it is generally hollowed to fit the timber. The cross-piece is not at right angles to the hanging-wall, as by cutting it a little too long and putting it in from above it sets more securely. The first model illustrates several cases :—

(*a*) In this, the simplest case, the cross-piece or stretcher is hitched directly to the foot-wall and wedged against the hanging-wall. This method may be used either to support the latter when it tends to break away in large pieces or, when both walls are strong, several stretchers with planks or poles placed above serve to support rubbish it is desirable to leave underground.

(*b*) Here the hanging-wall is weak, so that the stretcher is wedged against a side-piece under the former, as well as being hitched in the foot-wall as usual.

(*c*) Here the foot-wall is weak, so that there is a side-piece against it into which the lower end of the stretcher is fixed, while its other end is wedged directly against the hanging-wall. The side-piece is kept out slightly by distance pieces at top and bottom so that the ends of the poles can pass between the piece and the foot-wall.

In the remaining cases side-pieces are used against both foot and hanging-walls, in (*e*) and (*h*) there are distance pieces as in (*c*) and also a plank placed between a side-piece and the wall; the planks support the inner end upon one set of poles while the side-piece itself supports the outer ends of the next set in front.

(*g*) In this case the hanging-wall end of the stretcher is not hollowed, but the front of the piece against the hanging-wall is flattened and a board introduced between it and the stretchers; the method of using poles for keeping the rubbish out of the level is also shown.

The second model illustrates three methods employed where the section of the level is trapezoidal.

(*a*) Here one side of the level is strong, so that a recess, cut in the upper part of it, is sufficient to support one end of the cap; the other end of the cap is supported on a post. For the joint, the top of the post is made horizontal and the cap bevelled to fit it.

(*b*) This illustrates complete frames composed of caps, posts, and transverse soles.

(*c*) This illustrates complete frames with longitudinal soles. Two methods of casing are shown: in one the slabs from the squaring of large balks of timber are placed on top of the caps and behind the posts, in the other pointed poles are driven forward. These poles are of sufficient length to stretch over three frames; in the sides they are arranged as in the last model, but in the roof the back-end as well as the middle is supported on a plank by small filling pieces, so that the ends of the next forward poles can pass between it and the cap.

The lettering in these models is in the opposite direction to that in which the level would be driven.

1052. Model of double timbering used in Saxony. (Scale 1 : 16.) Received 1865. M. 2803.

The section of the level being rectangular, casing planks can be driven ahead of the frames, to serve as an advance shield in bad ground.

Double and single frames are put in alternately, so that a particular plank in the roof goes over the small inner part of a double frame, over the intermediate single frame, and finally over the outer part of the next

double frame. Three sizes of frames are necessary: the largest 9 ft. high and 5·5 ft. wide, the smallest 8·25 ft. high and 4 ft. wide, while the intermediate frame is 8·5 ft. high by 4·5 ft. wide. The double frames are placed 6 ft. apart with the single frames midway between. The joints are made by halving the ends of the cross-pieces and notching the tops of the posts. The casing planks are fixed firmly in position by wooden wedges.

Space for a water course is left by supporting the wagon-way about 15 in. above the floor on cross-pieces let into the posts.

1053. Model of timbering used in the Furness district. (Scale 1 : 12.) Received 1859. M. 2809.

In the hæmatite mines of Lancashire and Cumberland, the iron ore is in large "pockets" and is worked downwards in slices some 9 ft. thick. The roof is composed of boulder clay, and is continually settling down as the timber is insufficient for its complete support, but as it only comes down gradually it forms a safe roof to work under. Unbarked larch is the timber chiefly used; after a working is abandoned, the timber is taken out as far as possible and used elsewhere.

The small shaft from which the straight level proceeds is a "rise," put up from the main level below; it is about 6 ft. by 4·5 ft. in plan and lined generally with 6 or 7 in. roughly squared Norway timber, each piece being halved at its ends to make the joint. Four pieces go to a set and the sets rest on each other. The rise is divided into two compartments, one serves as a passage for the ore into the main level below, and is closed at the bottom by a slide so that the ore can be run as required into a wagon and taken to the shaft; the other compartment serves for ventilation and as a ladder-way, The frames are composed of two inclined side-pieces "collared" at the top to receive the round cap or head-tree. To prevent side pressure from forcing the props inwards dowels 1 in. in diam. are inserted in the head-trees. The frames are placed about 2·3 ft. apart, and until they get the "weight" from above are kept in place by means of "spiles"—small planks 4·5 ft. long and 1·5 in. thick. Another use of spiles is to form an advance shield to protect the men who are working in the "fore-breast," the small planks pass under the last but one and over the last head-tree. The settling down of the roof bends the spiles into the position in which they are shown in the model. The small branch level shows the spiles simply placed above the head-trees. The model shows the wheelbarrow formerly used, but now replaced by wagons running on steel rails.

1054. Models of Cornish methods of timbering levels. (Scale 1 : 12.) Received 1883. M. 2794.

In the first model the frames are composed of a horizontal cap rebated at both ends to receive the tops of two inclined side posts; the rebates prevent the posts being forced inwards by side pressure. The frames are placed at a distance of 1 to 3 ft. apart, and when necessary a sheathing of laths is placed behind them. The model shows a close casing, but this is not always necessary, it being often sufficient to place a few laths behind the posts and in the roof.

In the second model the only difference is that the side posts are vertical instead of inclined.

1055. Models of masonry supports in levels, used in the Saxon mines. (Scale 1 : 16.) M. 2805–6 & 2808.

The first model shows a level driven along a vein where the hanging-wall is sound and needs no support; an arch is built on the foot-wall side from the floor to the hanging-wall.

The second shows a small gallery with sides in hard rock; the roof is supported by a segmental stone arch.

The third shows a portion of a large adit level or water gallery, the upper part of which, constituting the wagon-way, is supported by an arch of masonry; the water is carried by a deep channel cut in the solid rock. In all three cases the arch stones are made of the gneiss of the district dressed to shape and set in cement.

1056. Model of composite level supports. (Scale 1 : 8.) Made by Herr Carl Schumann, 1880. M. 2814.

This illustrates a case in which one end of girder or piece of old rail is supported on masonry and the other end on a timber post, with a notch on the inside of its upper end, against which rests a piece of iron riveted to the cap and intended to prevent the side-piece being thrust inwards. On the top of the post is placed a piece of iron plate to form a bed for the cap.

1057. Model of level with metal supports. (Scale 1 : 8.) Made by Herr Carl Schumann, 1880. M. 2811.

This shows a case where a wide level, as at a shaft bottom, is supported by steel girders and hollow cast-iron columns with flanges at both ends resting on transverse soles. The cross-pieces support steel joists running in the direction of the level. Wooden lagging in the roof is added, and wooden slabs are placed behind the posts to prevent the sides coming in. The floor is laid with flat plates which allow of the wagons being readily turned in a small space, or placed on the return line.

1058. Models of metal supports for levels, used in Saxony. (Scale 1 : 8.) Made by Herr Carl Schumann, 1880. M. 2812–3 & 2816.

The first model shows a case where one side of the level is strong and the other weak; on the strong side the girder rests in a recess cut in the rock, and in the other is supported by a prop of the same section as itself. To prevent the posts being forced inwards, small pieces of iron are riveted to the underside of the cap near the two ends. The props rest on small plates of iron on transverse wooden soles. A lagging is placed between the girders, the arched platform thus made supporting the rubbish left after the removal of the ore by "stoping." Similar lagging is placed between the posts.

In the second model the level has strong sides, but the roof is supported by arched metal rails springing from the sides and resting on end bearer plates.

The third model is an example of a narrow level for a single wagon road with both sides supported by metal rails.

The fourth model only differs from the last in being wider for a double wagon road.

1059. Models of levels supported by curved iron frames. (Scale 1 : 8.) Made by Herr Carl Schumann, 1880. M. 2815.

The material is brought underground in a bent form, a whole frame being formed of one length of iron. The frames are footed in iron shoes fixed at the correct angle in a transverse wooden sole.

The first model shows a narrow level, and the second a wide one for a double wagon-road, supported by curved rails in iron or steel, and lagged with round timber. In the wide level an iron prop is added under the centre of the frame.

This series of models shows how when first used metal supports were applied in the same way as those of wood. Metal frames may, however, be

made of any shape or curvature and with adequate strength at the joints, so that a more economical distribution of material is obtainable than is possible with wood.

1060. Models of Comstock level timbering. (Scale 1 : 12.) Received 1883. Plate I., No. 7. M. 2796.

These show a special system of level timbering first used in the Sutro tunnel on the Comstock lode where the ground was loose and swelling, and heavy pressures on all sides had to be resisted.

In the first case the framing is trapezoidal, as in Cornish practice (*see* No. 1054), but with the addition of transverse sole pieces rebated to take the posts. In the second case the cross section of the level is modified to an irregular hexagon; in both cases the frames are made of heavy timber, often 12 in. sq., jointed in a special manner and lagged continuously on roof, floor and sides with planks closely set together. Wagon-ways are also shown.

1061. Model of timbering for chambers. (Scale 1 : 12.) Received 1883. M. 2797.

The model shows the "square set" system of timbering overhand stopes, which was first used on a large scale at the Comstock lode, Nevada, U.S.A.; since then it has been used in many localities (*see* No. 1062). The method consists in building up within the chamber, as the ore is extracted, a framework of skeleton rectangular prisms. The timbers are frequently squared and ended by special machinery.

The timbering of the excavation is begun by laying down horizontal pieces called "caps" and "ties" at right angles to each other and notched at each end so that where four pieces meet each forms a shoulder for the other; a central socket is left which receives the thinned away end of an upright post. On the top of the post is then erected a second floor of caps and ties, and so on; when the limit of the deposit is reached, short posts cut to lengths suited to the irregularities of the boundary are used and thick planks fixed against the rock to prevent pieces falling away. When necessary the sets can be strengthened by struts; the timber is often filled with rubbish from the ore deposit or sometimes with rock specially quarried. In dry mines this extensive framework of timber is a source of considerable danger through fire.

The joint in use on the Comstock is comparatively simple, the short tenons at the foot of each post resting directly on the long upper tenon of the post beneath. Timber 12 in. sq. is used, and the posts are 7 ft. 2 ins. long, including tenons while the caps and ties are 3 ft. 9 in. in the clear.

1062. Model of "square-set" timbering. (Scale 1 : 12) Presented by Cedric Vaughan, Esq., 1895. M. 2763.

This represents the timbering employed at the Hodbarrow hæmatite mine, Cumberland. The system is a modification of the Comstock timbering (*see* No. 1061), but has the joint designed by Mr. Vaughan.

The posts have similar ends with short tenons and shoulder rebated out; the ends of the caps and ties are rebated on three sides only. The timbering is 7 ft. in the clear both ways, while the distance in the direction of the working face is 4 ft. clear. A swing saw and mortising machine were put down for preparing the timber from pitch pine balks, 9 to 12 in. sq.

Although more expensive than the timbering used elsewhere in the district (*see* No. 1053) it more than repays the extra cost by its strength and greater convenience.

1063. Model of Newhouse adit level. (Scale 1 : 12.). Presented by Prof. Le Neve Foster, 1896. M. 2941.

This tunnel, situated at Idaho Springs, Colorado, U.S.A., was undertaken in 1895 to undermine at an average depth of 2,000 ft., a mountain of mica, schist and gneiss traversed by gold and silver bearing veins.

The tunnel is 10 ft. wide by 9 ft. high, and has a gradient of 1 in 240. It carries a double line of rails, 18 in. gauge, with a space of 30 in. between. Beneath them is a wooden drain, 2 ft. wide by 14 in. deep, the top of which serves as a footway. As however but little water was met with, this drain was utilised for ventilation by connecting it with a fan at the mouth of the adit. Dynamite was the explosive used, and at intervals of about 100 ft. short crosscuts were driven to serve as shelters for the men when blasting.

The timbering represented was only required for the first 80 ft., as after that distance the rock was sufficiently sound. The frames are of 9 in. square timber, and are placed at 5 ft. centres with intermediate struts and an outer covering of planks. In shape they resemble the irregular hexagon adopted in the Sutro tunnel (*see* No. 1060).

1064. Model of water-tight closure for a level. (Scale 1 : 12.) Made by Herr Carl Schumann. M. 2807.

This illustrates a method used in Saxony about 1840 of so closing a level as to prevent the entrance of water even under very considerable pressure; such a form of dam can only be erected where the strata are sound.

The work is commenced by hewing a recess in the walls of the level, so as to form a skewback or abutment for a domed arch with its convex face towards the water. This dome is built of carefully shaped wooden blocks, laid dry with the joints closed by wedges, first of wood and finally of iron. While the dome is being built a hole is left near the bottom to prevent water accumulating till the dome is completed; near the centre a manhole 21 in. diam. is provided which can be closed by a leather or rubber-jointed cover.

1065. Model of Saxon mine in the 18th century. (Scale of workings and details 1 : 36.) M. 2823.

The three portions show vertical sections of the shaft and workings of a lead-ore mine. The shaft has a lined way for the skips, a ladderway for the miners, and also contains two sets of pump rods, with the early pumps and wooden pipes, or "trees," that rendered pumping in stages necessary. These pumps were driven by an overshot waterwheel on the surface, vertically above them.

The model shows two methods of winning the ore, in one case by "overhand-stoping" in which the refuse material, if sufficient, forms the working platform and is supported over the levels by timbers; in the other, or "underhand-stoping" system, the refuse is supported by timbers over the workers; in both plans the area of the working face is increased by the stepped arrangement adopted. The employment of windlasses in small shafts is shown, also the planked way over which the boxes were slid before the general introduction of rails and wheeled trucks.

1066. Model showing methods of winning coal. (Scale 1 : 600.) Presented by C. L. Wood, Esq., 1852. M. 1393.

The model represents a stratum of coal which is being removed by four different systems:—

A. is the so-called "board and pillar" system, formerly employed in the Newcastle district. The whole of the ground to be taken away is divided into two sets of parallel galleries intersecting at right angles, thus leaving rectangular pillars of solid coal. When the galleries or "boards" have been carried out to the boundaries, the

pillars are finally removed and the excavation allowed to close. As the pillars are of comparatively small size, they often give rise to a "creep" or thrusting-up of the floor.

B. is an improvement of the above, also employed in the Newcastle district. Such a distance is kept between the two systems that they may be isolated, and the proportion of coal taken away in driving the boards is less, so that larger pillars are left.

C. is the "long-wall" method of working, in which the coal is taken away in one breadth without leaving any pillars. The roadways, by which the coal is conveyed to the shaft, are carried through the waste or "goaf," the sides being kept up by walls made of the *débris*.

D. is a modification of the "long-wall" method in which transverse lines of pillars are left at intervals, to support the roadway. In both C and D the working face is broken up by rectangular off-sets, the face nearest the shaft being kept a little in advance of its neighbour.

The whole area is worked from two adjacent shafts one of which serves as the downcast and the other, provided with two furnaces, for the upcast. The air currents follow the direction of the arrows, and are directed by solid barriers or by double doors. Pins represent the timber props employed during the cutting of the coal.

1067. Model of ironstone mine. (Scale 1 : 600.) Presented by Messrs. J. & J. W. Pease & Co., 1862. M. 1409.

This shows the method of working Cleveland ironstone at Upleatham. (*see* No. 1074). As shown in adjacent drawing of the strata, the bed of ore is 12–14 ft. thick divided by a parting of iron pyrites. The lower part of the bed only is worked; this is done by driving headways 9 ft. wide and 90 ft. apart; from them at intervals of 30 ft. cross levels 15 ft. wide are excavated, thus giving a series of pillars 90 ft. long by 30 ft. wide. These are finally removed with a loss of only 10 per cent. of their contents, or a total loss of 7·5 per cent.

1068. Model of Dolcoath mine. (Scale 1 : 576.) Made by T. B. Jordan, Esq., 1839. M. 2786.

This shows the surface arrangements and a vertical section of this extensive tin and copper mine at Camborne as it appeared in the year 1839. The red wood represents granite and the white the clay slate of Cornwall; the lode is shown by the black layers.

1069. Model of Holmbush mine, Cornwall. (Scale 1 : 720.) Made by T. B. Jordan, Esq., 1865. M. 1557.

This model follows the system employed in drawing mine plans, the whole of the excavations made, whether shafts, levels, or lode removed, being represented in colours, while the untouched surrounding material is left blank: the reverse method of treatment is represented in the model of Dolcoath mine, where the excavations are represented in the more natural though less convenient manner.

In the model the sections by horizontal planes at vertical intervals of 60 ft. are secured to brass frames, upon which are stretched cross wires representing the lines of northing and easting as usually drawn on mine plans.

The workings on each lode are distinguished by special colours as follows:—Holmbush lode, red; flapjack lode, yellow; lead lode, blue; cross courses, green.

1070. Model of Japanese mine. (Scale of details 1 : 30.) Presented by J. G. H. Godfrey, Esq., 1877. M. 2822.

This is a native model illustrating the method of mining for gold and silver in Sado Island. The entrance to the mine is by a timbered passage or adit in the side of the mountain; the level and shafts are timbered with round timbers and packing. Notched bamboos are used as ladders but many of the miners are working on light suspended platforms. The removal of the material is done in packs carried on the back.

1071. Models of Tyrolese methods of salt mining. (Scale 1 : 4800.) Made by Bergmeister T. G. Ramsauer, 1858. M. 2649.

These mines are situated in the Duchy of Salzburg. The rock consists of a mixture of clay with more or less salt, interspersed with veins of gypsum. Sections are shown on the sides of each model, and the different levels are represented on superposed plates of glass.

The working of these mines has been carried on from very early times, the present system being introduced in 1311. A series of levels at heights of about 120 ft. are driven into the hill side, and small branch levels are driven from these obliquely into the workings. The mouth of the branch level is dammed up and the whole chamber filled with fresh water, which is allowed to remain in the workings till it contains 27 per cent. of salts (or 25 per cent. of Na Cl); it is then run off to the boiling houses, which are sometimes 10 miles distant. For driving the levels, sinking winzes, &c., jets of water under pressure are utilised, a method introduced by Herr Ramsauer in 1841.

1072. Model of Clunes gold mine (1858). (Scale of details 1 : 48.) Presented by the Port Phillip and Colonial Gold Mining Co., 1865. M. 1558.

Clunes, in the district of Melbourne, is the locality where, in 1851, gold was first discovered in Victoria, and it was at this mine in 1857 that the milling of gold quartz was first practised in Australia. The model shows, in a general way, sections of the ground and workings, as well as the original arrangements at the surface for separating the gold from the quartz, which, as this plant inaugurated the system of treatment generally adopted throughout the continent, possesses exceptional interest.

The sections indicate four main lodes running nearly N. and S. but dipping steeply, as well as a number of smaller veins or leaders of varying inclination and thickness, while the surface shows how, owing to the lodes or quartz veins being harder than the enclosing rocks, the outcrops appear in a ridge projecting above the general level.

The preliminary operations in opening the mine consisted, as is still usual, in sinking small shafts, the mouths of which were packed up by timber logs, so as to form tips and also to carry the windlasses by which the skips were raised. When the value of the lodes had thus been ascertained, a deep main shaft was sunk, from which, at vertical distances of 60 or 100 ft., cross cuts, or tunnels, at right angles to the run of the lodes, were driven. When the lodes were reached, levels were driven along them and the vein-stuff removed by stoping.

The pit-head frame over the main shaft was arranged for winding with a flat rope and a skip running in guides; the work was done by a single cylinder engine and a multitubular boiler, which also actuated two lines of pump rods in the shaft.

On arriving at the surface the quartz was tipped into wagons and, if necessary, calcined in a kiln to render it sufficiently friable, but this practice was superseded in 1865 by the use of a stonebreaker. The quartz was then conveyed by an incline to the hoppers at the back of the stamp battery, from which it was fed to the stamps by shoots having a jolting motion.

Originally there were only 20 stamp heads, but in 1859 this was increased to 44; they were in four batteries, and were similar in construction to those shown in No. 1154. Two of the batteries were driven by Jordan's single cylinder engine (*see* Catalogue, Part I.), taking steam from a water-tube boiler; another by a semi-portable engine and boiler, and one by a horizontal engine on a cylindrical return-flue boiler. The fuel used throughout was wood, for preparing which a circular saw was provided.

The material from the mortar boxes was cleaned up at intervals in cradles (*see* No. 1127), while that discharged through the screens passed first over a "well," or shallow trough containing mercury, and then over a series of inclined tables having low steps covered with blankets. This system of collection was adhered to throughout the Clunes district, but elsewhere has been superseded by the usual amalgamated plates. The auriferous sand entangled in the blankets was removed at frequent intervals, by washing the blankets in a tub of water and collecting the gold by barrel amalgamation and a shaking frame, or even by hand washing; any pyritic tailings from the barrels were afterwards separately treated by finely grinding them with mercury under edge runners. The amalgam was filtered by squeezing through buckskin, and the solid remainder treated by distillation in the pots shown set in the brickwork of the return flue boiler. The gold was taken to Melbourne on a pack-horse, escorted by mounted police, for whom a station was erected at the mine.

HAULAGE AND HOISTING.

1073. Model of self-acting incline. (Scale 1 : 24.) Made by Herr Carl Schumann. M. 2791.

This form of haulage in which the full wagon draws up the empty one is convenient and economical where the incline available is at least 1 in 30.

In the simple arrangement shown, which is for use underground, the timbering is of round posts with a cap supporting boards. The incline is 1 in 7, and the wagons are attached to ropes which wind in opposite directions on two horizontal drums at the summit of the incline. A wooden brake lever is forced on the shaft between the drums to control the speed. There are two lines of rails, but in long roads it is usual to reduce the number of rails to three, or even two, and use turnouts where the wagons pass one another. Usually also a level section at each end of the incline, on which to prepare the wagons, is provided, and also a steeper section near the summit by which to accelerate the starting load quickly and so increase the average speed.

1074. Model of self-acting incline. (Scale 1 : 16.) Presented by Messrs. J. & J. W. Pease & Co., 1862. Plate II., No. 4. M. 1409.

This incline is situated at the Upleatham ironstone mines in the North Riding of Yorkshire, and is used to lower the stone from the headways (*see* No. 1067), which are driven into the face of the cliff, to the level of a branch of the North Eastern Railway.

The ore is drawn from the workings in small trucks of 20 in. gauge, hauled by wire rope driven by steam power, and then taken by locomotives to the head of the incline. After passing a weigh-bridge each truck enters a tipping cage controlled by a strap-brake, which discharges the stone into an inclined shoot closed by a flap also controlled by a strap-brake. This shoot, which holds the contents of several of the small trucks, then discharges into 3-ton wagons in the deep level cutting at the head of the incline. A train of loaded wagons being made up, it is lowered down the incline by a wire rope from a double drum, which, at the same time, winds

up a train of empty wagons. The drums are of cast iron, with wrought iron strap-brakes controlled by a hand lever.

In the model, the portion of the incline shown, which is 1 in 16, has been cut into three lengths and placed side by side, to reduce the length.

1075. Models of skips. (Scale 1 : 8.) M. 2819.

The skips used in Saxony are of wood bound with iron straps and lined with sheet iron. Two straps passing round the sides and bottom carry the guide rollers, and by two short chains form the attachment for the hoisting rope. One of the skips has a hinged door.

The skip used in Cornwall is made entirely of iron. It runs on four rollers and has four projecting plates beneath to keep it on the guides. There is a hinged door in front with a gravity-locked bolt. Flat rope is used.

1076. Models of wagons and tramroads. (Scales 1 : 10 and 1 : 12.) M. 2817.

The simple wooden end-tipping wagons are used in Saxony. The body rests on a single timber to which the axles are attached, and this block is made sufficiently deep to allow the wheels to be wholly under the floor for protection. The stress on the axles is reduced by iron plates, extending from the sides of the wagon to the axles. The wagon road is raised above the floor of the level to give space for a waterway; in one model the road is laid with T-headed rails, and in the other with flat iron set on edge.

The wagon used in Cornwall is wholly of iron. The body is set forward on the frame so that it nearly balances on one of the axles on which it tips upon releasing a catch at the rear. The end door is hinged and retained by a bolt at the bottom. The wheels are protected by a guard on each side riveted to the body. As in the previous cases, the wheels are loose on the axles.

1077. Haulage clip. Presented by J. W. Smallman, Esq., 1889. M. 2787.

This clip is for rapidly attaching a tub or wagon to the wire haulage rope travelling along the mine road; the form shown was patented in 1883 by Mr. Smallman. Two cheeks, tied together by a bolt, are extended at the lower part to form two jaws 4·5 ins. long, which are lined with soft iron. The insides of the cheeks are formed as inclined planes upon which works a block at the end of a clamping lever pivoted loosely in the cheeks. The lever forces the cheeks outward so causing the jaws to grip the rope. The shackle is for attachment to the tub or wagon.

1078. Model of mining windlass. (Scale 1 : 12.) Presented by J. Lace, Esq., 1893. M. 2780.

This model shows a simple form; the axle is a square iron bar lagged with two pieces of oak turned cylindrical after fixing. It is supported over the shaft by bearings in two iron brackets fixed to uprights at a height of about 3 ft. above the platform level. The uprights are tenoned into two cross-pieces and stayed by inclined struts; the axle is locked by a catch fitting over the square part. A sliding board closes the mouth of the shaft when the bucket is not being drawn through; it is further protected by a sloping board resting on the struts.

1079. Models of Saxon windlasses. (Scale 1 : 8.) M. 2636–7.

The first is similar to the preceding, but there is a space at one end covered by a trap door through which the ladders can be reached. The axle, which is 6 ft. long by 10 in. diam., is supported on the top of two uprights; a horizontal rail is provided to assist the workman when lifting

the loaded bucket away from the mouth of the shaft. The windlass is locked by a pin, pushed into a hole in one of the uprights.

The second is intended for heavier work, and is geared in the ratio of 3 : 1; the axle is 5·3 ft. long and 15 in. diam.

1080. Model of Saxon hand whim. (Scale 1 : 12.) M. 2638.

This is a form of capstan with the drum above, arranged for working by three men; as the whim cannot be placed directly over the shaft, guide pulleys and frames are necessary. The ore is held in wooden skips on which are rollers running between two wooden guides, and the skip is tipped by a projecting iron rod fixed at a short distance above the pit top; the two ends of the rod form bolts which are shot forward and retain the skip when it is lowered, while the upper end of the skip falls forward and discharges the contents over a wooden apron which directs the ore into a wagon. A brake fixed to the lower drum and worked by a hand lever controls the motion at any point.

The wagon shown is the Hungarian "hund"; it has two pairs of wheels of unequal diameter. The miner presses the handle at the back so that the load rests on the big wheels which run on a plankway.

1081. Model of Cornish horse whim or gin. (Scale 1 : 12.) Made by T. B. Jordan, Esq. Received 1842. M. 1392.

This is a winding gear specially constructed for being worked by horse power; before the introduction of the steam engine these machines were generally used for raising the ore from mines, and for temporary works; this arrangement is still frequently adopted.

The horses are harnessed to two radial arms built into an upright axle, on which is a drum 12 ft. diam. by 4·6 ft. long formed of boards nailed to three wooden rings secured to the upper portion of the axle. The top bearing of the axle is carried by a timber framing, to which the framing for the pulley of the rope or chain over the pit's mouth is also secured.

The circular path described by the horses is 36 ft. diam., and the load is raised at a speed of 75 to 100 ft. per min. in kibbles holding about 280 lbs.; for depths exceeding 240 ft. two horses are generally employed.

1082. Model of Saxon horse whim. (Scale 1 : 24.) M. 2639.

The axle is 23 ft. in length, and has the rope drums placed on its upper end as in the hand whim; the horses are harnessed to a turning bar attached to the lower end of a diagonal arm. The lower drum is rigidly fixed to the axle, while the upper drum is connected to the lower one by a wooden pin, which when withdrawn enables the lengths of the ropes to be adjusted, so that when one bucket is at the level the other shall be at the surface. In making the adjustment the upper drum is fixed by the brake and the lower one turned round to the required amount. The upper drum runs on friction rollers on the upper surface of the lower one and the brake works on the lower projecting rim of the upper drum. The foot-step bearing of the axle rests upon a pair of adjusting wedges on a short pillar of masonry; the top is attached to a horizontal beam carried by two diagonal struts which also support a conical roof covering the drums. To take the load from the horses when the whim is stopped, two poles with spiked ends are dragged round with the horse-pole.

1083. Model of Cornish water whim. (Scale 1 : 12.) Made by J. Arthur, Esq. Received 1843. M. 1383.

This shows a method of raising material from mines by water power. A simple overshot water-wheel drives, by spur gearing, a horizontal shaft on which are fixed two bevel wheels, and this shaft can slide in its bearings sufficiently to bring either of the bevel wheels into gear with a third bevel wheel connected with the winding drum; by this arrangement the direction of winding is reversed. The drum shaft is provided with a strap brake, and

there is an arrangement by which a weight sliding in front of a signal board indicates the position of the bucket or kibble. These kibbles each hold about 3·5 cwt. of ore.

1084. Model of water whim used in the Harz mines. (Scale 1 : 18 for the wheel and 1 : 12 for the winding gear.) M. 2640.

This arrangement is adopted underground in some German mines, for utilising water power for winding in shafts which do not come to the surface.

An overshot water-wheel, 29·25 ft. diam. by 5·5 ft. broad, is provided with two sets of buckets opening in opposite directions; each set is supplied from a separate sluice (not shown in the model) so that the wheel can be rotated in either direction, an arrangement described by Agricola in 1554 and introduced into the north of England about 1778. The model shows in detail the construction of this double wheel in timber. The two winding drums, 8·5 feet ft. diam. are on the same shaft as the water-wheel; the one nearest it is made entirely of wood and fixed to the shaft, while the other is loose and carried by six cast-iron arms on either side turning on a pair of cast-iron rings keyed on the shaft; each of these rings has four square holes in it to receive the locking hooks, which by an external lever may be caused to lock the drum to the shaft in any position. This arrangement allows of winding from different depths, by adjusting the lengths of the two ropes; brakes on each edge of the loose drum are provided. A wooden brake-wheel 12 ft. diam. is fixed to the main shaft which is 23 in. square and has journals 6 in diam.

1085. Model of Saxon turbine whim. (Scale 1 : 12.) Received 1868. M. 1414.

This represents the system of winding adopted about 1856 at the Oberes Neues Geschrei Mine, Freiberg, where the shaft is sunk on the vein, dipping at an angle of 70 deg. All the machinery is underground, but is controlled from the surface by rods.

Power is supplied by the discharge of 75 cub. ft. of water per min. under a head of 97·5 ft. which is utilised to drive either of two turbines placed side by side on the same shaft, one for backward and the other for forward motion. The turbines are of the kind introduced into Saxony about 1849 by Schwamkrug with radial outward flow, the water entering a part of the circumference only so that a large wheel can be used and thus the speed of revolution be reduced. The rings of buckets are attacked to a stout disc which serves also as a brake drum, and the speed is reduced in the ratio of 14 : 1 by the gearing connecting the wheels with the winding drum. The supply nozzle gives a rectangular jet which is adjustable in area by a movable flap.

The tub or skips carry about 8 cwt. and run on rollers between wooden guides; there is a tipping gear worked by a lever for emptying them.

1086. Model of steam whim. (Scale 1 : 12.) Made by T. B. Jordan, Esq., 1843. Plate II., No. 5. M. 2641.

This arrangement was once common in Cornwall for winding from shallow shafts by steam power. The model shows a plant designed by Mr. J. Sims and erected at East Wheal Crofty.

A beam engine, by means of bevel gearing, turns two horizontal winding drums 4 ft. diam.; these are so arranged that the engine can wind from two shafts at the same time, guide pulleys and frames of simple construction directing and supporting the chain to the shafts. The mouth of each shaft is protected by two hinged doors with a slit in the middle of each for the passage of the chains; the ascending kibble raises the door, which falls down as soon as it has passed. The ore is brought up in kibbles of wrought iron; their weight when empty is from 6 to 10 cwt. and their load from 5 to 7 cwt.

1087. Model of skip-way adapted for winding. (Scale 1 : 24.) Presented by Capt. Wm. Teague, jun., 1882. M. 2790.

This is a model of a skip-way which was in use at Dolcoath and Tincroft mines, Cornwall. It represents a common form of way arising from the practice of following the lode closely.

Where the skip-way is vertical, or nearly so, four timber guides are used so as to completely control the skips, but where less inclined the lower guides only are retained, as the weight of the skips then keeps them steady, while their absence saves timber, and also leaves the skips more accessible. At the top of the model is seen the flap that retains the skip at the surface when being discharged. The skip is shown in an adjoining case.

1088. Model of skip-way for a crooked shaft. (Scale 1 : 24.) Presented by Capt. Wm. Teague, jun., 1882. M. 2789.

The model shows an extreme case of a crooked shaft, the result of following a lode downwards on its dip.

The skips used in Cornwall are sheet-iron boxes running between wooden guides, and usually have two rollers and two slippers on each side, In such an exceptionally crooked way as that shown there were no slippers to the skips, but four wheels on each side (*see* model in adjoining case), so that on the reversed part of the curve also the load on the guides should be carried on rollers. The hauling rope is retained in a central position in the shaft by numerous wooden rollers on the concave side of the course.

1089. Model of winding arrangements. (Scale 1 : 48.) Presented by Capt. Wm. Teague, jun., 1882. M. 2789a.

This is a diagrammatic model showing the winding and pumping arrangements adopted in working the Highburrow lode at the Carn Brea mines at Redruth, Cornwall. To render the model more compact, the distances apart of the shafts and adits have been much reduced,

On the left is shown a shaft, fitted with guides for winding, and a set of mining pump rods, that work pumps which divide the total lift into three stages. The water raised is delivered into an adit considerably below the top of the shaft. From these rods power is, moreover, transmitted by inclined rods and bell-cranks to a pump in another section of the mine. On the right is represented a winding shaft, with timber guides for the skips, and also an inclined skipway running into it close to the surface. One of the skips is also shown.

1090. Model of pit shaft with cage and guides. (Scale 1 : 12.) Presented by T. Sopwith, Esq., 1853. Plate II., No. 1. M. 1403.

The earliest system for raising coal in the pit appears to have been in "corves," *i.e.*, wicker baskets hung loosely from the lifting rope. The only improvement seems to have been the provision of a partition to separate the ascending from the descending corves. John Curr, in 1788, patented the use of guides in which worked a cross-bar carrying the corves. This was not generally adopted outside the Sheffield district. With the advent of the steam engine greater speeds became possible, and were necessary as greater depths were reached. It was not, however, till 1835 that the present arrangement, combining the use of guides with a cage in which wheeled tubs from the working faces were raised to the surface, was after several trials brought to a success at Woodside, near Ryton-on-Tyne, by Mr. T. Y. Hall. It was found possible to deal with a much greater quantity of coal than before, and the new system rapidly extended into all districts.

The model was made in 1835, and shows a rectangular cage of wrought iron bars with a wooden floor having rails for the tub. The flat hempen lifting rope is attached to the cage by four chains and a spring hook. The pit guides are flat iron bars spiked to the face of continuous timbers;

above the pit bank the guides are of lighter section, and at right angles to the position of the former; the shoes on the cage are of channel section; "keps" to rest the cages on during the time of changing the tubs were also applied. These were simply hinged frames caused to swing inward under the cage by a lever. The pit-head pulleys are of cast iron, carried in a timber framing strengthened by inclined struts.

1091. Model of pit-head frame and cage. (Scale 1 : 16.) Presented by H.G. the Duke of Buccleuch, K.T., 1844. M. 2785.

This shows an early form of cage, which was used at Cowden Colliery, Dalkeith, N.B., consisting simply of a platform supported from the flat winding rope by chains attached to iron uprights, which carry shoes that embrace the wooden guides. Modern cages, being also used to convey the miners, are closed at the sides, while the ends have light detachable gates. In America, however, a cage like the one in the model, with the addition of a hood, is common. To support the cage at exactly the right level while the full wagon is being replaced by an empty one, catches consisting of planks running across the shaft, set on edge and hinged below, are secured so that their upper edges may project a little into the cage space. By a hand lever both catches can be moved back so as to leave the shaft clear. Flat rope is used, working on a reel or bobbin with long horns, the rope coiling upon itself. Large pulleys are used in the pit-head frame, which consists of a pair of upright legs stayed in the direction of the drum by long wooden struts.

1092. Model of cages and guides. (Scale 1 : 12.) Presented by G. B. Forster, Esq., 1862. M. 1404.

The pair of cages shown are arranged for carrying four wagons each. They are built of flat iron bars with diagonal braces, and have a wrought-iron roof and two decks. The guides are a pair of flat-footed rails, arranged on one side only, and secured to cross sleepers placed 6 ft. apart through the entire depth of the shaft. The case has three pairs of crescent-shaped slippers riveted to its guided face.

1093. Model of pit-head frame and cages. (Scale 1 : 12.) Contributed by W. H. Jordan, Esq., 1865. M. 2644.

The overhead pulleys are carried by a braced timber framing, the members of which are secured together by long tie-bars and angle plates. One of the back legs is provided with steps and a hand-rail, by which the bearings of the overhead pulleys can be readily reached. The pulleys have cast-iron grooved rims and wrought-iron arms.

The shaft has three timber guides for controlling the two cages, and these guides also form gripping surfaces for the safety gear, which automatically comes into action should the rope break. The catches consist of two levers on each side of the cages, the outer ends of these levers being pulled down by springs that tend to close the catches on to the guides; the pull of the lifting rope is partly felt by these levers, and as its action is greater than that of the springs the safety catches are swung clear of the guides so long as the pull of the hauling rope is maintained.

The guides are carried to the pit-head frame and are employed to support the cage in the event of overwinding, but in later arrangements a form of detaching hook is usually employed which will itself retain the cage when overwound, independently of the safety catches. The detaching hook shown, however, consists of three plates provided with notched slots, into which the hoisting tackle of the cage fits. The notches are kept out of line by a spring, but when overwinding occurs the hook is pulled through a conical socket that pushes the three slots into line, so releasing the cage and allowing the winding rope to run freely through without being broken.

The cages are single decked, framed in iron, closely boarded, and provided with a semi-circular roof; the floor of each cage has a catch that retains the trucks in position by their axles. When at the ground level the cages are retained by four side catches, each of which has to be withdrawn by treadle levers before a descent can be made.

1094. Model of cage with loading gear. (Scale 1 : 8.) Lent by B. Woodworth, Esq., 1893. M. 2542.

This shows a two-decked cage fitted with the "automatic controllers," patented in 1890 and 1892 by Mr. Woodworth, by which the requisite number of wagons are automatically passed into the cage and there locked, and again released without requiring "scotching" or personal attendance. In the model the cage has its lower deck arranged for tilting, and is fitted with controllers at each end to allow for loading and unloading at opposite ends, if required, but the upper deck is on a fixed incline with single controllers only. A controller consists of an arm which swings upward so as to catch the wagon axle, and which can be depressed by a bolt moved by a lever on the side of the cage, either automatically or by hand. As the wagon axles pass over the controller each axle partly rotates a star wheel which, after two or more axles have passed, throws back the bolt and allows the arm to lift and so prevent more wagons passing. For safety, two controllers acting on the same axle are used.

1095. Model of cage with safety catches and disconnecting hook. (Scale 1 : 6.) Received 1851. M. 1399.

The model shows Messrs. White and Grant's catches and hooks introduced about 1850. The cage is a simple stirrup frame, with a platform having rails for two wagons side by side. The guides are of timber, and the slippers of channel iron; the safety catches consist of four eccentric discs keyed on each end of two horizontal shafts carried in bearings on the top of the cage. These catch shafts are turned by the action of springs that tend so to rotate them as to close the catches on to the guides, but the pull of the hauling rope tends to rotate them in the reverse directions.

The disconnecting hook consists of a hook in a frame, engaging in an eye secured to the end of the lifting rope; the hook has a projecting tail which when overwinding occurs strikes the overhead framing, and so turns the hook as to release the rope, the guides and safety catches then support the cage.

1096. Cage with safety catches. (Scale 1 : 12.) Contributed by James Owen, Esq., 1862. M. 1391.

This is a light cage with a metal roof and floor; it is guided by four channel-shaped slippers working on timber guides. On each side is also a plate that carries the fulcrums of two catch levers whose gripping surfaces are formed with teeth; the catches are forced up by four separate springs, which are, however, overpowered by the pull of the hoisting rope so long as the rope is intact. In the model a wagon is shown in the cage retained in position by two connected end clips. This form of safety gear was patented by Mr. Owen in 1857, and soon extensively adopted in Lancashire; in one case a load of two tons moving at the rate of 10 ft. per second was brought to rest in a distance of 3 ft. after the breaking of the rope, while in two other cases loads of 15 cwt. and 41 cwt. were stopped after a fall of 1·5 and 2·5 in. respectively.

1097. Model of skip with safety gear. (Scale 1 : 5.) Contributed by W. Bennetts, Esq., 1862. M. 1386.

A Cornish skip with four wheels and slippers (*see* No. 1075), is shown with its guides. The safety gear, patented in 1859, by Mr. Bennetts, consists of two toothed levers, pivoted on the same centres as the upper wheels, and is

forced on to the guides by volute springs when not overcome by the pull of the hoisting chain transmitted to them by levers attached to the crutch which moves in slotted holes in the skip.

1098. Model of cage with safety catches and disconnecting hook. (Scale 1 : 8.) Contributed by J. T. Calow, Esq., 1862. M. 1401.

The cage has a pyramidal roof covering the safety gear. The catches are applied by a weight, supported by a coiled spring in a vertical cylinder. If the rope breaks, the fall of the cage at first is quicker than that of the spring-supported weight, and the catches close; with the model the action appears to be instantaneous.

The disconnecting hook was patented by Mr. Calow in 1859 and 1862, and is similar to Whitelaw's (*see* No. 1100), the jaws being kept expanded in the socket by the action of a spring, which is overcome when external projections from these jaws encounter a collar in the head frame.

1099. Model of cage with safety catches and disconnecting hook. (Scale 1 : 8.) Contributed by J. K. Hampshire, Esq., 1862. M. 1384.

The arrangements shown were patented by Mr. Hampshire in 1862. The cage has two decks and a projecting iron hood; it is guided by four channel slippers sliding on timber guides, which also receive the grip of the safety catches. The catches consist of a pair of levers on each side of the guides, and are forced on by plate springs arranged under the upper deck. The cage is lifted by extensions of the catch levers, which are curved so as to form hooks which engage with lugs on the cage, so that the lifting pull is directly met.

The disconnecting hook consists of a pair of cross levers, which, by the weight of the cage, are closed together round the end link of the hauling rope; the upper ends of the levers are prolonged beyond the jaw as horns which are wedged open by the top of the frame when overwinding occurs, the jaws are thus opened and the rope released, the safety gear then being relied upon to retain the cage.

1100. Model of cage with safety catches and disconnecting hook. (Scale 1 : 12.) Contributed by John Whitelaw, Esq., 1862. M. 1389.

This is a light metal cage, working in timber guides on to which spring-moved safety catches press and close should the rope break; the grippers of the catches have enlarged roughened faces. The weight of the cage is taken by the stops of the catch-levers; the closing spring is a bar supported in its middle by a bracket inside the hood.

The disconnecting hood consists of two claws forced asunder by a spring between them; these are enclosed by a socket which has internal grooves, and is attached to the cage. When overwinding occurs the claws are drawn through a ring fixed in the head timbers, which closes the claws together, and so releases the cage, which is then retained by the safety catches.

1101. Models of cages with wire guides and safety catches. (Scale 1 : 6.) Made by J. P. Harper, Esq., 1869. M. 1388.

Two examples are shown, one a single cage with two wire rope guides, the other a two-decked cage to carry four wagons, controlled by four wire guides. In the two-decked cage the guide ropes are each enclosed by two slippers attached to the sides of the cage, but the safety catches are applied only to two of the wire ropes, which are diagonally opposite. The pull of the hoisting rope is taken by four chains attached to the top of the cage, but a portion of the pull is also taken by a bar connected with two

plungers in spring boxes; should the hoisting rope fail, the spring will force the plungers downward and so close the nipping levers on to the rope guides. In the single cage the whole of the weight is taken by the beam that applies the safety catches; shoulders on the plungers preventing any over-compression of the springs. A model (scale 1:2) of the catches for the rope is also shown.

1102. Model of pit head gear with cages and detaching hook. (Scale 1 : 24.) Presented by E. Ormerod, Esq., 1880. Plate II., No. 2. M. 1387.

A pithead frame, built up of timber, and a simple form of iron cage, with wire guides, are shown.

The detaching hook for the prevention of overwinding, was patented in 1867 and 1875 by Mr. Ormerod; it acts by disconnecting the shackle from the rope, while at the same time supporting the cage in a bell-mouthed casting provided for the purpose on the pithead framing.

The hook is a scissors arrangement of three plates pivoted on a central pin; the upper ends of the plates are slotted and notched in such a way that the pin of the rope shackle in the normal position is firmly retained, accidental displacement being guarded against by a shearing pin passing through all three; the lower ends of the plates are spread out, and have slotted holes, through which passes the pin of the shackle attached to the cage. When overwinding occurs, and the hook is pulled into the fixed bell-mouth, the spread out ends are forced together, thereby shearing the pin and releasing the rope shackle, but, at the same time, opening the plates at the top, and causing the notched ends to overhang the bell-mouth, so as to prevent the descent. The holes in the lower end of the plates are so shaped that when the hook releases above, the lower shackle pin drops into a position that prevents the plates again closing.

1103. Model of disconnecting hook. (Scale 1 : 6.) Presented by J. King, Esq., 1875. M. 1402.

This form, patented by Mr. King in 1867, and subsequently improved, consists of two outside plates, connected by a shackle with the top of the cage, and containing between them two jaws or opposite hooks, pinned together, which cross each other, and retain the rope shackle. Below the central pin they are extended, so as to form levers that will open the jaw when over-winding occurs, and they are drawn through a fixed socket; this opening causes the shoulders on the jaws to engage on the fixed socket which thus retain the load. A copper shearing pin prevents accidental disengaging.

1104. Model of safety gear. (Scale 1 : 16.) Presented by the Royal Commission on Accidents in Mines, 1886. M. 1400.

Two cam catches on a single horizontal shaft are employed; on the shaft is a horizontal lever carrying a weight the downward action of which is resisted by a vertical helical spring of less travel. If the rope breaks, the lever-weight at first falls less rapidly than the cage, and so applies the catches (*see* also No. 1098).

1105. Model of cage with disconnecting hook. (Scale 1 : 6.) M. 1390.

The cage is of simple construction, but shows a longitudinal shaft with projecting ends, which, when swung round, retains a wagon in position by its top.

The disconnecting hook, which was introduced by Messrs. Ramsey and Fisher, is of the disconnecting and sustaining type. It consists of two jaws that between them, grip the shackle of the hauling rope; these jaws are carried in a block to which they are hinged at their lower extremities, and are hooked at their upper outer edges, so that when opened to release the

lifting rope in a case of overwinding, the hooks will lodge over the top edge of the socket fixed in the head framing, and so retain the cage. In ordinary work the jaws are kept closed by two side keys that fit between the jaws and the block, these keys have enlarged heads that project through the block. When overwinding occurs, the keys are forced downward so freeing the jaws, while they also act on the tails of the jaws so as to open them; a central wedge also assists in opening the jaws, as it is pulled up by two side plates connected by shearing pins with the rope. To prevent an accidental release, two metal pins are provided that must be sheared by the keys before the latter can move, these affording a resistance that only actual overwinding wonld overcome.

1106. Model of proposed safety gear. (Scale 1 : 8.) M. 1385.

This is a cage with four pairs of catches arranged to cut into the timber guides; the weight of the load is taken directly by the lifting chains, while the cage is lifted by lugs, resting on the platform. The idea of the inventor was to use the weight of the load to move the catches, should the rope break; but as the cage and load fall at practically the same rate, the catches are not applied, and without springs the arrangement is useless, a fact that the model will clearly demonstrate.

1107. Model of detaching hook. (Scale 1 : 3.) Made by Messrs. T. Walker & Son. Received 1897. M. 2967.

The model is fitted with framing, and an overhead sheave to indicate the pit-head gear and to support the experimental load, when the detaching gear releases it from the lifting rope. The hook consists of a pair of hinged jaws which can be closed together round the pin of a shackle permanently attached to the winding rope; the jaws are kept closed by a collar beneath them. When overwinding occurs, the detaching hook is drawn up through a conical socket secured to the framing, but the socket, being too small to allow the collar of the hook to pass, is drawn down the hook, and by its action on the lower end of the jaws, opens them, so releasing the shackle, and preventing the breakage or straining of the rope. The expanding jaws of the hook are, however, too wide to pass through the fixed socket and so are retained, notches on them giving further security by engaging over a ring on the upper edge of the socket. To prevent the retaining collar from accidentally dropping, and so releasing the hook, two metal pins are inserted, each of which must be separately sheared by the collar before it can drop, so that only by considerable force can the position of the collar be altered.

1108. Model of disconnecting hook. (Scale 1 : 10.) Presented by Messrs. Joseph Wright & Co., 1904. M. 3373.

This is a modification of King's original detaching hook for the prevention of overwinding (*see* No. 1103); it is arranged on the upper portion of a wooden pit frame so that its action can be shown.

The improvements, patented in 1896 and 1900 by Messrs. E. G. Weddell, J. G. Chamberlain, and R. Player, consist in cutting away the two outer fixed plates at the jaws on opposite sides and thickening up the inner scissors-like plate so as to be flush, thus giving increased bearing area to the shackle. They also provide the scissors plates with two pairs of catches. Should overwinding occur, one pair of catches begins to project simultaneously with the opening of the scissors plates; should the overwind be complete the second pair come into operation and prevent the shock and damage which would otherwise ensue in falling on to the catch plate. The small shackle shown is used, in the hole provided, to lift the catches off the catch plate and lower the cage to the pit bank so as to allow the shackle of the winding rope to be again inserted.

1109. Model of man-engine. (Scale 1 : 24.) Made by T. B. Jordan, Esq., 1842. Plate II., No. 3. M. 1398.

The man-engine is a machine introduced in the Harz in 1833, but since used on the Continent and in Cornwall to a considerable extent, as a means for assisting the miners in ascending, and in some mines descending, the shaft. The earlier form with two rods is less used than the single rod arrangement.

This model represents an engine with two rods connected to a pair of reversed T-bobs, which mutually counterbalance. These rods are rocked from a crank driven by an engine or water-wheel and are guided at intervals by flanged rollers, while on their fronts at distances of 10 ft. are projecting platforms, about 14 in. square, connected on the outside by a handrail. To ascend, the miner steps on to a platform and when it has reached the top of its travel steps on to a platform on the adjacent rod, which is then at the bottom of its stroke and will take him up the next stage, when he steps on to another platform on the first rod, and so on.

The first double-rod man-engine built in Cornwall was erected in 1843 and reached a depth of 1,740 ft. It was worked by a steam engine of 36 in. cylinder diam. by 6 ft. stroke, making 15 revs. per min. and driving the rods by a crank making 3·5 revs. per min. with a stroke of 10 ft. The men were lifted at a speed of 73 ft. per min. and 24 mins. were requisite for the entire journey.

1110. Model of German man-engine. (Scale 1 : 16.) M. 2825.

This represents a double-rod engine erected near Freiberg in 1857. The rods are 8·5 in. sq., have a stroke of 56 in., and are guided by wrought-iron bars bolted on them and working in fixed plates secured to cross timbers placed at intervals of 48 ft.; stops are fixed to the backs of the rods at intervals of 18 ft. to retain them should the mechanism fail. The rods are connected together at intervals by chains passing over sheaves and thus counterbalance each other; the bearings for these sheaves completely obstruct the rods and have to be passed by the men on fixed ladders. The small platforms shown have no hand-rail but a handle is fixed above each at a convenient level.

1111. Model of Cornish man-engine. (Scale 1 : 8.) Received 1859. Plate II., No. 3. M. 1397.

This, the first single-rod man-engine, was erected at the Fowey Consols Mines, Cornwall, in 1851; several other examples have since been constructed.

The rod extends vertically from the surface to a depth of 1,680 ft., and is driven by an overshot water-wheel 30 ft. diam. by 6 ft. face, making 3 revs. per min. A crank on the axle of the wheel is directly connected by a bob by which the rod is given a stroke of 12 ft. The rod is 8 in. sq. and built up of timbers 36 ft. in length, butting together and connected by fish-plates, each 12 ft. long. The rod platforms are 12 in. sq., with handles of ·75 in. round iron 2 ft. long fixed 4 ft. above them: similar handles are placed at the stationary platforms upon which the men rest during the alternate strokes. The weight of the rod is counterbalanced by three bobs, two of which are underground.

1112. Model of the surface arrangements of a coal-pit. (Scale 1 : 24.) Presented by John Wales, Esq., 1858. M. 2642.

This model represents the arrangements formerly adopted in the large collieries of Durham and Northumberland.

A is a vertical, single cylinder, high pressure, direct acting winding engine. Above the cylinder is the crank-shaft on which are the fly-wheel

and the drums with the flat rope used for winding, as well as a smaller conical drum which raises the small coal to the screens L by means of a chain. The piston rod is guided by Watt's parallel motion, and the cylinder is supported on a cost-iron column at a considerable height above the ground. On the fly-wheel is a strap brake applied by the engineman's foot. The exhaust pipe is carried through the cistern from which the feed pump draws the supply for the boiler.

B are two Lancashire boilers each 30 ft. long by 5 ft. diam.

CC is the pit-top—a timber platform carried on columns 16 ft. above the ground in order to facilitate screening and loading. The "keps" or catches for the cage are nearly vertical wrought iron bars, two on each side of a cageway; they are fixed to horizontal bars which, by a single rotation from a handle, move them in or out of the cage-way—a device still fairly common. The platform is covered with cast-iron plates to make a smooth surface on which to manipulate the tram wagons.

DD are two-decked cages formed of three wooden platforms kept at a fixed distance apart by wrought iron struts. Catches, attached to the roof of each deck, lock the wagons on the cage.

E is a water balance for bringing each deck of the cage in turn to the floor level of the bottom of the pit. It consists of two vertical cylinders communicating with one another, in which work pistons attached to platforms upon which the cages rest. The pistons are further counter-balanced by weights so that either platform of the cage may be brought to to the floor level without the help of the winding engine at the surface.

FF are tipplers or cradles; these are wrought-iron frames mounted on trunnions so that when a full wagon is run on, it overbalances and is emptied, being then readily brought back to an upright position. A hinged flap on the top prevents premature discharge and undue breakage of the coal. In tipping, the long tail of the latch strikes against a projecting wooden block at the head of the screen.

GG are tram wagons or "tubs," made with wood bound with iron and each carrying about 8 cwt.

HH are chaldron wagons (*i.e.*, having a capacity of 53 cwt.) for surface transport; they are of a type which has survived from the time when horses were employed for drawing, but are now, except for local traffic, replaced by larger 6-ton wagons.

II are screens, consisting of rectangular riddles, 18 ft. long by 6 ft. broad, with parallel iron bars ·625 in. apart, and set at an angle of about 34°. The round coal is discharged directly into railway wagons while the small coal is collected in hoppers communicating with K.

J is a stage on which is thrown the shale, &c., picked from the coal while it is on the screen and in the wagon. When a quantity has accumulated the sliding doors are opened and it is shot into wagons which remove it to the spoil-bank.

K is a box-wagon by which the small coal from the hoppers is carried up an inclined plane to the screens L. The wagon is counterbalanced, and is hauled by the chain from the winding engine A.

L are screens for the small coal, which make three sizes, "nuts," "seconds," and "duff" or "slack," which are discharged through the shoots M, N, and O; the slack, when sufficiently clean, is used for making coke or patent fuel.

The distinguishing letters correspond with those on the engraved plate attached to the model.

VENTILATION AND LIGHTING.

1113. Model of ventilating furnace at Hetton Colliery. (Scale 1 : 24.) M. 2618.

This model represents a furnace of the largest type, as used in Durham, and is so arranged that the amount of grate surface in use may be varied according to the requirements of ventilation.

The furnace stands between the return air-way and the upcast shaft in a chamber opened out of the solid coal, lined with ordinary brick and with a segmental arched roof. The firegrate is level, measuring 25 ft. by 5 ft., and has side walls and a semicircular arched roof of firebrick; the large openings at the ends of the bed are for the passage of the foul air over the fire. Stoking is done through four pairs of side doors over which are four holes for the admission of air above the fire; the stoking space is 7 ft. wide on this side, and behind are two recesses 4 ft. sq., for storing coal; the other side of the furnace is 2 ft. from the wall of the chamber. The upcast shaft is 9 ft. diam., lined with brickwork. Two furnaces in connection with this pit passed a current of 104,000 cub. ft. of air per min., at a pressure of 1 in. of water (5·2 lbs. per sq. ft.).

Where there is any danger of explosion resulting from fire-damp in the foul air, it is delivered by an inclined or "dumb" drift at a point some distance up the upcast, the fire being fed with fresh air from the downcast; this practice is general where furnaces are still in vogue.

1114. Model of South Wales colliery ventilating furnace. (Scale 1 : 24.) Presented by Messrs. Vivian & Sons, 1856. M. 2617.

This is a type of underground furnace once very common; it consists of a plain rectangular firegrate placed at the lower end of a short drift or level which rises at an angle of about 13 deg. towards the upcast shaft. The drift, being in the coal seam, is lined with brick; the furnace is covered by an inner lining of fire-brick leaving a space between the two, divided by arched diaphragms to form air passages to keep the outer arch cool. To obtain more complete combustion of the smoke and gases from the furnace, a transverse perforated pipe is introduced just behind it, and is supplied with air by a funnel-mouthed pipe set to meet the draught. The upcast shaft is four-sided in section, the sides being formed by two pairs of arcs of different radii.

1115. Model of ventilating furnace. (Scale 1 : 12.) Presented by J. M. Paull, Esq., 1858. M. 2619.

This furnace was patented by Mr. Paull in 1857, but never came into extensive use; it is intended for use in fiery collieries where the foul air must not come into contact with the flame.

The firegrate is enclosed in a square shaft-like chamber with an arched roof from which a chimney extends into the upcast shaft. A number of copper tubes, the greater number horizontal, but the lower ones inclined, are placed across the furnace. On the one side these communicate with the return air-way and on the other with the upcast, so that a current of air is established from left to right. The products of combustion are only brought into contact with the foul air at the top of the chimney where the temperature is considerably reduced. The fire is fed with air direct from the downcast. The patentee recommended that the tubes should be at least 6 ft. long increasing in diameter from the intake to the outlet; the diameters recommended were 6 to 9 in.

1116. Model of mine with double ventilation. (Scale 1 : 792.)
Contributed by W. Oliver, Esq., 1842. M. 1394.

This model of a coal mine worked on the "board and pillar" system (*see* No. 1066), illustrates Mr. John Buddle's system of double or compound ventilation for fiery collieries.

The seam is an inclined one, dislocated by a downthrow fault near the centre; the shafts are sunk at the lowest point, and the workings are carried on towards the rise. The workings on either side of the fault are distinct, but are put in communication by a pair of drifts driven through the fault.

The ventilating furnace is at a short distance from the upcast shaft, in the centre of a rectangular block bounded by two parallel inclined drifts and two transverse horizontal ones; the return currents of air are controlled by six doors, marked A to F, in these four drifts. The currents of air from the districts D and G pass over the furnace, while those from E and F, being fiery, are passed to the bottom of the upcast by a dumb furnace so as to obviate direct contact with the fire. If the air in D becomes fiery it is thrown on to the dumb furnace by opening the doors A and B; by suitably arranging the doors other conditions can be met.

1117. Model of self-closing door for airways. (Scale 1 : 16.)
Contributed by T. Heaton, Esq., 1865. M. 2620.

The current of ventilating air sent into the downcast would pass directly to the upcast shaft were it not for doors placed across the roadways, for by these the air is caused to circulate in sections round the working faces. Important doors, where there is heavy traffic, are, as a rule, opened and shut by boys stationed at them.

The model shows an arrangement, patented by Mr. Heaton in 1856, whereby the wagons in a coal mine on their approach open the door, which after their passage again closes. The doors are of the sliding type carried on inclined rails above, so that they have a natural tendency to run together and so stop the passage. On either side of the doorway are two long levers pivoted to the side of the working but having their free ends inserted in the doors. The front of the wagon is fitted with a metal loop that, acting as a wedge, separates the levers and opens the doors, retaining them open until the wagon has passed.

1118. Miners' lighting appliances. Plate II., No. 6.
M. 2826–2893, &c.

The examples in the Museum illustrating the development of lighting in mines are too numerous to have separate entries in the Catalogue, and are, therefore, dealt with collectively.

The **open oil lamp** was successfully adopted for miners' use at a very early period. This, the **spout lamp,** and **tallow candles** in holders, are still common, especially in metalliferous mines. Early in the 18th century it was found that the air of certain coal mines contained gas which caused explosions with naked lights. The light of sparks from flint and steel in the **steel mill** was possible in such places, but gave a miserable light, and was extremely costly. It was not till 1815, when Sir Humphry Davy's attention was directed to the subject, that a practical safety lamp was devised. Davy found that small tubes, perforated metal or wire gauze, will so cool a flame attempting to pass it as to prevent the ignition of inflammable gas on the other side; this principle he embodied in the **Davy** lamp, and it has been relied upon for the security of all safety lamps up to the present. George **Stephenson** was independently experimenting at the same time with a lamp in which the air was admitted to the flame through small tubes; this he developed into a successful type. Owing to the low illuminating power of the Davy, Dr. W. R. Clanny in 1839 replaced the lower part of the gauze by glass, above which the feed air enters. In 1840, as an outcome of

an inquiry in Belgium, Mr. J. Mueseler independently brought out his lamp which resembles the **Clanny** externally, but has a conical metal chimney supported by a gauze diaphragm inside the gauze case; this led also to the invention of the **Boty** (1844) and the **Eloin** (1846), in both of which the air was fed in below the glass. Safety lamps were made compulsory in Belgium in fiery mines in 1851; of these, in 1864, the **Mueseler** alone was permitted. As it was found that the proportions of the lamp affected its safety, these have been fixed by law in Belgium since 1876.

Davy had pointed out that if the flame impinges on the gauze in draughts, &c., or if the fire damp burns inside the case and the gauze cannot conduct away the heat rapidly enough, flame will eventually pass. Experience had shown this to be the case prior to 1835. To obviate the danger, as the velocity of ventilating currents steadily increased, shields were devised. The experiments carried out by the Royal Commission on Accidents in Mines in 1879–1886 showed that many lamps then relied on were unsafe owing to the absence of shields or bonnets and drew attention also to many new lamps, *e.g.*, the **Gray** (1868), with tubular feed, subsequently developed into the **Ashworth-Hepplewhite-Gray** testing lamp and the **Marsaut** (1883), with double conical outlet gauzes. The latter was the outcome of experiments, which showed that the volume of a lamp should be small; that the height and diameter of the glass should be reduced as far as possible; that the outlet gauzes should be conical, and that a shield and bonnet for this gauze were necessary. Practical considerations necessitate that weight should be kept down; that holes and gauzes should not be quickly choked by dust, and that the parts should be few and admit of being quickly cleaned, and assembled. The latter operations, as well as filling and lighting, must be done each time a lamp is used, and necessitate considerable outlay for lamp rooms and lamp trimmers. As many as 20 per cent. of the lamps are sometimes accidentally extinguished during a shift; to obviate bringing them to special lamp stations, relighting devices are employed. such as **Wolf's** fulminating strip or high tension electric spark in conjunction with a benzene lamp.

The difficult problem of preventing the miner risking his life and those of his comrades by opening his lamp while at work has led to the invention of numerous locking devices. In the order of time they are the screw; the padlock; the lead plug or rivet and various forms of mechanically, pneumatically, and magnetically controlled bolts. The lead rivet is by far the commonest; the lamp can be opened, however, but not without detection. Another method is to ensure that the act of opening the lamp shall put out the flame by some form of extinguisher of which the **protector** lamp is the best known example.

The incandescence electric lamp has been adopted on the mine roads, &c., but for working faces generally the system is hardly flexible enough. The portable storage battery lamp has been used, but its weight and cost are, so far, great drawbacks.

For detecting the presence of fire-damp the bluish aureole it imparts to a flame is observed. Ordinary lamps, especially the **Gray**, give reliable indications when 2·5 per cent. is present, but alcohol is relied upon for smaller quantities, and lamps employing this have been worked out by **Pieler, Chesneau, Stokes,** and others.

1119. Shaw's gas tester. Received 1901. M. 3166.

This is an apparatus patented by Mr. Thomas Shaw, of Philadelphia, in 1887–88, for rapidly estimating the amount of deleterious gas present in the air of a mine. This it accomplishes by determining the volume of methane, or other combustible gas, that it is necessary to add to a sample of the mine air to render it explosive; these samples are collected from various parts of the mine in india-rubber bags filled by means of a diaphragm pump.

The testing apparatus consists of two single-acting pumps, one of which is the larger and is for pumping mine air from a sample bag, while the

smaller one is for drawing combustible gas from a holder. These pumps are arranged under a graduated beam, which can be oscillated by a crank motion; but the stroke of the gas pump is adjustable, owing to the distance of this pump from the beam fulcrum being variable. The graduations on the beam are so marked that they directly give the percentage which the gas from the smaller pump forms of the total volume discharged by the two pumps. Through these pumps the air and gas is sent, by mechanically moved valves, into a mixing valve and then into a chamber provided with a firing gas jet at an orifice near the middle while one end is closed with a cap which, when displaced by an explosion, strikes a gong.

When testing a sample from the mine the position of the smaller pump is successively varied until an explosive mixture is obtained, when, from the readings on the beam, the percentage of added gas is ascertained; from corresponding results obtained with pure atmospheric air the percentage of "fire-damp" in the mine atmosphere is determined by subtraction.

The apparatus is similarly used for testing for "choke-damp," or carbon dioxide, the gas cylinder being, however, thrown out of action by sliding it under the fulcrum. A quantity of mine gas is then pumped through lime water until it attains a standard degree of turbidity, usually that obtained by passing through it a half cylinder-full of a 1 per cent. mixture of carbon dioxide and air. The amount of mine air necessary to give this degree of turbidity is read off from a graduated scale attached to the piston of this pump.

COAL TIPS.

1120. Model of apparatus for shipping coal. (Scale 1 : 20.)
Presented by Messrs. Vivian & Sons, 1856. M. 2645.

This was constructed for loading Welsh steam coal, an operation which requires special arrangements to prevent breakage, the coal being very tender.

The wagon, which has a bottom door, is lowered bodily into the hold of the vessel by a platform slung by flat ropes from the four corners, and guided by slides fixed to the quay wall. The ropes run over pulleys on the top framing and are wound on drums on a shaft which has also on it two other drums on which coil in the opposite direction flat ropes attached to balance weights. The weight of the loaded wagon being in excess of the counterbalance, the platform descends, winding up the weights as it falls; when the wagon is emptied the weighted ropes unwind from their drums and bring the platform back to its original level. The speeds are regulated by wrought-iron brake-straps working on two brake wheels geared to the drum shaft.

1121. Model of apparatus for shipping coal. (Scale 1 : 20.)
Presented by Messrs. Vivian & Sons, 1856. M. 2646.

In this arrangement the coal is brought alongside the quay in wrought-iron boxes provided with hinged doors at the bottom held up by chains. Each box is slung from the end of a crane jib when in the vertical position, and is then lowered outwards over the quay wall into the hold of the vessel; the weight of the jib is counterbalanced by a weight sliding in a box behind. The coal box can be raised or lowered independently of the jib by means of a geared windlass fixed on the ground; the weight of the box is counter-balanced, and there is an arrangement for letting go the hinged doors. Strap-brakes are provided for controlling the motions.

1122. Model of coal tip with anti-breakage box. (Scale 1 : 12.) Lent by the Taff Vale Railway Co., 1896. Plate II., No. 7. M. 2959.

This model represents one of a large number of coal tips working in the Cardiff district, and has special arrangements to avoid the breakage of some of the tender coals raised in South Wales.

The coal is brought in end-tipping wagons, running on a high level road, along which the empty wagons are afterwards returned. The full wagons run directly on to rails on a lift platform or cradle, which by a brake is allowed to sink to the height of a discharging shoot that receives the coal when the cradle is tipped. The weight of the cradle and empty wagon is more than counterbalanced by weighted chains, which when the wagon is discharged, will restore the cradle to the higher level after the controlling brake has been released; the work is entirely done by the weight of the descending coal.

From the shoot the coal may fall directly into the vessel, but generally is lowered by anti-breakage boxes which, when the bottom is reached, are opened and so deliver the coal without shock. The return of the empty box is performed by a counterbalance weight, as with the cradle.

These tips are fitted with hydraulic tipping rams, for lifting the back end of the wagon or cradle when the shoot is discharging from a low level line into a high ship. In such circumstances the anti-breakage box is worked by an independent hydraulic ram.

In the model a second and later form of anti-breakage box is also shown, but not in position. This larger box, known as the "Thomas–Bachelor" box, is so constructed that while remaining closed when suspended it opens when an attached chain is tightened. When it has discharged, a counterbalance weight immediately lifts the box, which automatically closes ready to receive its next charge of coal; this quick-working box is in use at the Penarth Dock.

1123. Model of coal tip. (Scale 1 : 16.) Lent by James Rigg, Esq., 1870. M. 2740.

This shows a form of tip for discharging coal from railway wagons into stores or the holds of coasting vessels and steam colliers. The object of this tip is, by using a projecting shoot, to avoid the fall and consequent injury of the coal, also to dispense with the employment of hydraulic or other power, by utilising gravity to cause both the forward and return motions.

The coal wagon has an end door for delivery, and is run into a strong shoot carried on trunnions. At the bottom of the shoot a spur quadrant is fixed, into which gears a pinion keyed to a shaft carrying a brake sheave. When a full wagon is home in the tippler, the shoot tends to tip forwards, and when the wagon is emptied, the tendency is to return to the horizontal position, control in all positions being secured by the strap brake provided.

1124. Model of coal tip and screens. (Scale 1 : 16.) Lent by James Rigg, Esq., 1870. M. 2741.

This shows an arrangement for discharging coal from the "tubs" or "corves" as received from the pit shaft, and classifying it by screens prior to its delivery into the respective wagons. It is particularly designed to avoid breakage of the coal.

The tip consists of a shoot, which oscillates upon trunnions through an arc sufficient to permit of the coal from the partially inverted pit tub leaving it freely but gently, and distributing itself over the screen. The tip is so balanced that the weight of the loaded tub causes the forward motion, and when the coal has been delivered on to the screen a counterbalance gives the preponderance needful to cause its automatic return;

the oscillation in both directions is controlled by a strap brake. The upper screen in this example consists of a series of fixed bars and the "round coal" passing over them is delivered to its wagon over a hinged door, while the "nuts" and "small" are separated by a lower shaking riddle oscillated by a hand lever.

1125. Model of gravity coal tippler. (Scale 1 : 8.) Lent by Messrs. Heenan and Froude, 1902. M. 3264.

This machine is for tipping the contents of pit trucks into railway wagons, or on to screening apparatus, simply by the weight of the coal discharged.

The tippler, patented in 1901 by Mr. C. E. R. Sams, consists of a skeleton horizontal drum, riveted up in steel, with three chambers through it, parallel with its axis and each provided with rails of the same gauge as the pit trucks; the chambers have also plated sides, from which two rails project so as to overhang the truck wheels and thus retain the truck when the tippler rotates. The drum can be locked in three positions, by a bolt engaging with three stops on the drum and controlled by a hand lever, and this lever also relieves two weighted strap brakes by which the speed of rotation is checked.

When a full truck is pushed into the drum it drives out an emptied one, and, then, upon the lever being pulled, its weight causes the drum to rotate, carrying with it also two emptied trucks, till it is retained by the next stop. The full truck in thus being turned through 120 deg. delivers its contents on to an inclined shoot immediately below the drum, so that there is but little fall to cause breakage of the coal. The discharging capacity is up to 10 trucks per minute.

ORE-DRESSING MACHINERY.

"Dressing" is the term generally used to include the various operations of preparing a mineral for the market or for the separation of its various constituents. The dressing required varies very greatly with the nature of the substance treated. Stone is simply reduced in size or dressed to shape; coal is either classed in sizes and hand-picked, or sized and the smaller classes treated in concentrating appliances, or washed; iron ore is simply hand-picked before undergoing metallurgical treatment. In the case of many ores, however, the treatment is of a more elaborate nature owing to the complexity of the ores, as, for example, when the ore of one metal is distributed sparsely through another. Such ores are generally subjected to a preliminary washing to remove the mud; this may also effect concentration, as in the case of gold-bearing alluvium, but generally the washing is followed by selective breaking with hand hammers and by hand-picking. Thus, three classes at least are made: (1) ore ready for the market; (2) lumps requiring further dressing; (3) refuse.

Sometimes, especially in German practice, many more classes are made by hand-picking; in this country and America, the preliminary washing and hand-picking are often dispensed with, and the ore taken directly to the stone-breaker. The finer

crushing of the whole or part of the ore is usually accomplished by rolls, stamps, or disintegrators. Sizing is usually performed after each breaking, to prevent waste of power and also to classify crushed ore into equal sized grains—a necessary preliminary for some concentrating processes.

Breaking appliances.—Breaking is done to some extent by hand-hammers, but more generally machines are employed in which crushing is accomplished by intense local pressure. For the preliminary breaking, crushing jaws are usually employed, and for the finer crushing, rolls, mills, or stampers are generally found most convenient; but where the material is particularly hard, the stamp battery, which is in reality an assemblage of tilt hammers, is almost exclusively used.

Sizing appliances.—These are employed to separate the crushed materials into particles of uniform bulk irrespective of any other qualities, and usually consist of some arrangement of sieves in series. The first sieve passes all but the very largest, the second sieve retains only the particles that are in size between its mesh and that of the first sieve, and so on, the classes obtained being always one more than the number of sieves. In spite of the comparatively small portion of the area of a cylindrical sieve that is doing work at any instant, it is the most generally used form for sizing ores, on account of its mechanical convenience, but for colliery work flat sieves are preferred because they cause less breakage.

Concentration.—This process generally depends upon the difference in density between the ore particles sought and those of its gangue, which, if they are of uniform size, causes a great difference in the rate at which they will precipitate through water. For example, two particles of equal size, one of galena (sp. gr. 7·5) and one of quartz (sp. gr. 2·6) will experience nearly equal resistance from the water, while the galena will be attracted downward with about three times the force that the quartz experiences. If, however, the galena particle was further reduced, a point would be reached when the two materials would fall at the same rate; in the case cited, the relative sizes of equal falling particles or "equivalents" is 4 : 1. If, then, an ore containing these two materials is classified so that no class includes grains of quartz four times as large as the smallest grain of galena, separation will be possible. In machines such as keeves and jiggers, in which the particles interfere with each other and their fall is no longer free, a still greater latitude in the sizing is found to be permissible. When the particles have a free path through water in which to settle, the machine takes the form of a jigger or hutching box that in its earliest stage consisted of a water tub in which a riddle containing ore was shaken. The particles settled to the bottom in the order of their densities, and the deposit was afterwards removed in

horizontal layers. Material from 1 in. to ·04 in. diam. can be successfully concentrated in this way.

If surface friction is also employed to assist in the separation, as when the pulverised mineral is carried by water over a rough inclined board upon which the ore deposits in bands of decreasing richness, the "table" type of apparatus is arrived at; the thin layer of deposited ore is easily removed by flushing with water. By using an endless belt or a circular table continuous acting machines of great capacity are thus constructed.

If the deposit is allowed to increase to a considerable thickness the table machine becomes a "buddle," from which the ore is removed by digging after a deposit of as much as 18 in. in depth has accumulated. To maintain a smooth surface on the deposit, mechanically moved brushes are continuously swept over it, thus avoiding the formation of furrows.

In nearly all ore-dressing operations the great difficulties arise from the large amount of useless material with which the valuable ore is associated, but as machinery and processes improve, it is continually being found that wastes rejected by earlier workers admit of profitable treatment.

1126. Model of Australian puddler. (Scale 1 : 16.) M. 2579.

This machine is used in Victoria to remove clay from gravel containing gold; the idea appears to have been borrowed from the similar machine used in brickmaking. It consists of an annular trench lined with iron or hard wood, and having in it triangular drags, attached to radial arms that are fixed to a central post. This post is directly rotated by a horse walking in a circular path or by other power, and the clay is so puddled by the drags that it is carried off by the water flowing through the trench, leaving behind a clean gravel which is then put through a cradle (*see* No. 1127) to collect the gold.

1127. Model of cradle and utensils for gold washing. (Scale 1 : 4.) Received 1856. M. 2580.

These appliances constitute one of the simplest outfits employed in alluvial gold digging, being readily obtained anywhere.

The cradle is a rough wooden box on rockers; in the head is an easily fitting sieve of perforated sheet iron into which is shovelled gold-bearing gravel or "pay-dirt," while water is poured over it by the tin dipper and the cradle is rocked by a handle. The gold, sand, and fine particles carried by the water through the sieve are guided by an inclined frame below the latter to the head of the box, and flow down the sloping bottom. A blanket stretched over the frame retains very fine particles, while coarse gold is caught by transverse ledges or "riffles" on the bottom. The pebbles left in the sieve are picked over by hand, in case a nugget is present, before being thrown aside. When there is sufficient accumulation on the bottom, the sand is separated from the gold by agitation in the tin dish in a tub of water. This method is slow and wasteful.

BREAKING APPLIANCES.

1128. Model of toothed roll crusher. (Scale 1 : 8.) M. 2631.

This arrangement of rolls was patented by Mr. H. Mackworth in 1856, as a means for breaking clay ironstone and so separating the contained shale. The two rolls are geared together and their surfaces are formed with blunt projections which alternate with each other but are not in contact.

1129. Models of stone breakers. (*a*) (Scale 1 : 2.) Presented by H. R. Marsden, Esq., 1869. M. 1129.
(*b*) (Scale 1 : 8.) M. 2632.

Mr. Eli Witney Blake, of Newhaven, Connecticut, U.S.A., introduced this stone breaker in 1853; since then it has come into most extensive use for crushing ore as well as for preparing road metal. The crushing surfaces consist of two fluted jaws of chilled cast iron with removable faces. One of the jaws is fixed, while the other swings on a shaft above and is reciprocated ·5 in. by a toggle-joint, formed of two plates, one butting against the lower part of the movable jaw and the other against the fixed framing of the machine; the toggle-joint is straightened by a connecting rod from an eccentric on the belt-driven fly wheel shaft and is restored by a spring. The stones drop deeper into the hopper-like space at each reciprocation and are crushed as the jaws close. The distance between the jaws can be adjusted by means of the wedge, placed between the back plate of the toggle-joint and the framing, so as to pass the fragments when reduced to the required size. These machines run at a speed of 250 revs. per min., and, according to size, break from 4 to 13 tons of rock per hour to a size of 2 in. cube.

The smaller model represents an early form in use in Saxony about 1865; it is slightly simpler in construction than the larger one, and is also less massive, but is stated to have been of about the same capacity.

1130. Model of stone breaker. (Scale 1 : 8.) Presented by W. H. Baxter, Esq., 1883. M. 1619.

This modification of Blake's machine was patented by Mr. Baxter in 1878.

The movable jaw is pushed forward in the usual manner by a toggle-joint, but the latter is raised by a second toggle-joint worked by a crank and horizontal connecting rod. By this compound toggle a so-called "knapping" motion is obtained, which it is claimed reduces the amount of material delivered as dust.

1131. Blake–Marsden stone breaker. Lent by H. R. Marsden, Esq., 1888. M. 1923.

In this modification of Blake's machine, patented in 1872 by Mr. H. R. Marsden, the jaw is moved forward by a disguised toggle-joint combined with a lever. The longer arm of a bell-crank lever is reciprocated vertically by a crank on the driving shaft, while the shorter end acts as a block between two toggle-plates, one of which abuts upon the frame and the other upon the back of the movable jaw. As in Blake's machine, the jaw is restored by a spring and the space between the jaws is adjusted by a wedge.

Driven by a belt and bevel gear from the fly-wheel shaft is a cylindrical screen for road metal; the holes are ·875 and 2·25 in. diam., so that three sizes are made.

1132. Stone breaker. Presented by Messrs. Robert Broadbent & Son, 1894. M. 2678.

In this modification of Blake's stone breaker, the reciprocation of the jaw is performed by an eccentric on the fly-wheel shaft driving the middle piece of a toggle joint, while the return stroke of the jaw is given by a separate toggle motion, working in tension and connecting the lower extremity of the moving jaw with the framing; an adjustable spring takes up any play. The cushions or bearings in which the main toggle arms or plates work are of steel, and drop into recesses which are narrow at the ends to prevent a broken cushion from working outward.

The screen is of two different diameters, superposed so as to reduce the length, and is driven as in the previous example; the perforations are ·2 in., ·8 in., and 1·5 in. diam., so that four classes are obtained.

1133. Ore crusher. Lent by the Gates Ironworks Co., 1891. M. 2399.

This is a crusher in which the reciprocating jaw of the ordinary machines is replaced by a gyratory crusher moving in a vertical conical shell; it was patented in 1881 by Mr. P. W. Gates, and subsequently improved. The upper end of the central spindle which carries the crushing head is socketed loosely in the top framing, so as to permit of the motion produced by the other end which is carried eccentrically in the boss of a horizontal bevel wheel from which the spindle gets its gyratory motion. The breaking head is of chilled cast iron, and tapers towards the top of the shaft, while the shell in which it works tapers downward and is fitted with chilled iron liners. Power is applied by a horizontal shaft which is connected to the heavy driving pulley by a readily renewable cast-iron pin, that in case of an accident will fail instead of any more expensive part. The material to be crushed is fed in through the openings at the top. The circular form of the crushers prevents the passage of unbroken flat pieces of rock, and the tapering of the crushing head spreads the material on to a larger surface as it is being reduced. The fineness of the crushed product is regulated by a set screw supporting the spindle. The broken material drops on to the shoot that covers the bevel gearing, and passes out through an opening in the shell (*see* sectional drawing, scale 1 : 8.) A machine capable of breaking 2 to 4 tons of compact gold quartz per hour is stated to require 4 H.P.

1134. Model of crushing and grinding mill. (Scale 1 : 4.) Received 1872. M. 1762.

In this machine, patented by Mr. G. H. Goodman in 1870–71, the ore is first broken by a jaw-crusher and then ground between horizontal discs. The jaw-crusher has a fixed jaw and also a movable one actuated directly by an eccentric on the driving shaft; the latter jaw has obliquely serrated chilled cast-iron faces, and by its motion exerts a combined grinding and crushing action.

The crushed material passes by a shoot into the hopper of a grinding pan below, which contains two horizontal cast-iron furrowed discs or stones in contact, the upper one being driven by gearing from the jaw-crusher. With gold and silver ores the pan can be used as an amalgamation mill, by constructing the lands of the stones with depressions to contain mercury.

1135. Hand-power crushing rolls. M. 2630.

This crusher was formerly used in small lead mines in Derbyshire. It has two plain cast-iron rollers 2·75 in. diam. by 8 in. long, connected by spur-wheels and driven by two hand-wheels. One pair of bearings is adjustable by set screws so that the size of the crushed material may be regulated. The ore is supplied through a hopper, to which is hinged a shallow inclined tray supported by two arms resting on the teeth of the

spur-wheel, which thus cause the tray to vibrate and deliver the ore uniformly to the rolls. The rolls are cleaned by scrapers pressed against them by weighted levers. The crushed ore is delivered by a shoot into a sheet iron dish.

1136. Model of Cornish crushing rolls for copper ores. (Scale 1 : 12.) Made by T. B. Jordan, Esq., 1842. M. 2629.

The rolls are driven through spur gearing in the ratio 4 : 1 by an overshot water-wheel 24 ft. diam. The rolls are pressed together by a weighted lever which will lift should an unusually large piece be passed. The ore is fed in by hand, and the crushed material is delivered sideways down an inclined shoot into a revolving sorting screen, formed of longitudinal bars. The stuff that will not pass between the bars is led into a box, which, when full, is drawn up by a windlass and the contents again passed between the rolls. The water-wheel drives the windlass, the shaft being lifted out of gear by a lever and kept in by a spring.

1137. Model of Cornish power-crushing rolls. (Scale 1 : 6.) Presented by John Taylor, Esq., F.R.S., 1851. M. 2628.

This is an improved form of roll crusher, employed at the Tywarnhaile mine, Cornwall, about 1850.

The rolls, which have thick cast-iron shells keyed on cylindrical centres, are 27 in. diam. and geared together; the driver is 24 in. long and the follower only 18 in. The follower is pressed against the driver by weighted bell-crank levers, which limit the pressure to a safe amount. The crushed stuff passes from the rolls into a revolving trommel, 42 in. long, 24 in. diam., covered with gauze of six holes to the square inch and having its axis inclined at 25 deg. The material which passes through the gauze is loaded by a shoot into trucks, while the coarse stuff is lifted by a raff-wheel, 15 ft. diam., and delivered on to the charging platform to be passed a second time between the rolls.

A crusher of this size makes from 30 to 50 revs. per minute, and requires from 12 to 20 H.P.; it will crush from 40 to 60 tons of ore per day.

1138. Model of Cornish crushing rolls. (Scale 1 : 24.) Presented by W. A. Thomas, Esq., 1871. M. 2633.

These rolls, used at Devon Consols mine, closely resemble the preceding, but in addition the arrangement of the mill with its floors is shown.

1139. Models of ball and pan crushers. (Scale 1 : 8.) Contributed by Hyde Clarke, Esq., 1859. M. 379.

These two models show the arrangement for grinding and amalgamating gold-bearing quartz, patented by Mr. Hiram Berdan in 1852.

The arrangement consists of a large open cast-iron pan about 6 ft. diam., revolving on an inclined axis and containing two cast-iron balls of unequal size, the larger one weighing about 3,000 lbs. In the model containing two pans, clutches on the driving shaft enable either to be thown out of gear. Ore, which has been coarsely crushed, is put in the pans with a little mercury, and as the grinding proceeds the gold is collected by the mercury; the lighter material is washed by water that is kept flowing into the pan through spouts near the edge of the pan as they come to the lowest position.

1140. Model of grinding mill and sifting machine. (Scale 1 : 12.) M. 2782.

This mill was used in amalgamation works in Saxony; it resembles in its arrangements an old-fashioned flour mill. The sifted ore from the drum sieve (No. 1162) is ground between granite millstones. The top millstone is

fixed on a vertical shaft and is driven, at 130 revs. per min., by crown bevel gear from a water-wheel (shaft only shown). The fineness of the grinding is regulated by lifting, by a screw, the beam on which rests the footstep bearing of the vertical shaft. A shoot leads the ground ore to a rotating cylindrical sieve, the angle of inclination of which can be adjusted; this sieve discharges through a door in the hutch into a wagon alongside; the ore is further treated in No. 1196.

1141. Model of Italian amalgamating mill. (Scale 1 : 8.) Made in the Museum, 1898. M. 3026.

This represents a pair of mills, 18 in. diam., used in the north of Italy for gold extraction. Several of these pairs are usually arranged in series on the side of a hill, so that the same water drives them successively. Each pair of mills is fixed on a platform, and each lower stone is contained in a timber vat, the space between the sides of which and the stone is rammed tightly with sand and moss so as to form a strainer. The upper stone or runner is driven by two iron pegs, projecting downward from a crosshead, which is secured to the top of a vertical shaft passing through a wooden bush in the lower stone down to a timber post below. This post is the vertical shaft of an impact water wheel, 4 ft. diam., resembling the modern Pelton, or "hurdy-gurdy," wheel. The wheel has 24 wooden vanes, slightly cup-shaped (an actual one is shown), and the driving water is brought to it by an inclined shoot or launder, the water reaching the wheel with a velocity of about 16 ft. per sec. The upper end of the launder opens into a head race where a wooden regulating sluice is provided. The lower floor of the mill is flooded with water while the wheels are in action, and the water, by sluices, is passed to the launders of the mills below.

Each mill deals with 73 lbs. of ore per day of 24 hours; the ore, which has already been treated by stamps, is fed into the mill at intervals; after running for 12 hours about 7 ozs. of mercury is added to collect the gold. The mill is flushed with water every eight hours, but the amalgam which collects in the packing within the tub is only occasionally withdrawn, through side orifices.

1142. Model of edge-runners for crushing "torta" (working). (Scale of details 1 : 8.) Received 1878. M. 1754.

This represents a special construction of edge-runners known in S. America as an "arrastra," and used in the Mexican amalgamation process for extracting silver; it is arranged to give the grinding and mixing action that, since the invention of the process in 1557, has usually been obtained by the long-continued tramping of mules within an inclosure about 50 ft. diam. Continuous attention was necessary to ensure uniform treatment of the mud in which the animals worked, but, by the simple mechanical arrangement shown, greater uniformity is secured with less labour.

A circular bed is prepared and paved with stone, and round this is constructed a low wall or tub of timber, while in the centre is fixed a massive stone that has secured to it a horizontal wheel of 49 teeth. A pin on this centre carries a short arm that has a pin on it to which a horizontal bar is attached. This bar has two wheels or edge-runners loose on it, and at its extremity is provided with attachments by which mules, walking outside the enclosure, can pull the bar round. The pin of the bar has secured to it below a pinion of seven teeth gearing with the fixed wheel, and by this epicyclic gear the centre of revolution of the bar travels round the fixed wheel, so causing the runners to cover in successive turns the whole surface of the floor. By the introduction of an extra tooth or hunting-cog into the fixed wheel, the places missed by this model would be covered. The narrowness of the runners and the flexible attachment of their bar avoid any necessity for great accuracy in the surface of the floor.

1143. Model of centrifugal pulveriser. (Scale 1 : 8.) Received 1905. M. 3405.

This model represents a grinding mill of the form patented by Mr. C. Lucop in 1875, and improved by Mr. J. U. Askham. Such mills are used for reducing cement clinker, lime, phosphates, slag, &c.

The machine consists of a steel ring clamped between the two halves of a cast-iron casing, within which revolves a double arm fixed to a central shaft, and carrying at its ends steel rollers whose axles are free to move radially in slots, so that when the shaft is rotated they move outward and grind the material against the ring. The previously broken material is fed into a hopper at the top of the casing, and is carried on to the roller path by revolving blades. The ground material is forced through screens placed over the ends of the casings by propellers fixed to the shaft at each side of the roller arms; it then passes by suitable channels through the bed of the machine whence it is removed by conveyors. The shaft is supported in a bearing at each end and carries a flywheel and pulleys. The mill has a grinding ring 24 in. diam., by 4 in. wide, and rollers 8 in. diam.; it runs at 260 to 300 revs. per min., and reduces about 30 cwt. of average material per hour, for which it requires about 5 h.p. It is fixed to a wooden frame mounted on a concrete foundation.

1144. Model of Huntington mill. (Scale 1 : 6.) Lent by Messrs. Fraser & Chalmers, Ltd., 1907. M. 3474.

This centrifugal roller and ring mill was brought out in 1883 by Mr. F. A. Huntington for wet pulverising and amalgamating gold quartz, especially if of a brittle or argillaceous nature; for this it is found superior to stamps, while its first cost, and cost of operation are considerably less.

The ore from a stone-breaker is fed automatically through a hopper at the side of the pan in the centre of which is a vertical shaft driven from below by reduction bevel-gearing, usually in the ratio 2 : 1. This carries a horizontal frame in which are three or more pairs of pockets which support yokes from which grinding rollers are suspended about 1 in. clear of the bottom of the pan. The yoke allows the roller, which is free to revolve on its spindle, to swing radially outward against a renewable steel ring lining the pan; the rollers, also, have renewable tires. The horizontal frame supports three or more fixed scrapers to throw the ore outwards; when pulverised, the ore escapes through screens round the pan above the grinding level, thence by an annular launder to copper amalgamating tables, &c. About 75 per cent. of the gold is caught by mercury lying at the bottom of the pan and the rest by the tables.

The mill shown is 5 ft. diam., crushes about 20 tons per 24 hours when running at 70 revs. per min., and requires 6-h.p. to drive it.

1145. Disintegrator. Lent by J. Harrison Carter, Esq., 1890. M. 2327.

In this machine the four beater arms are of iron with hardened steel faces, the sides have renewable serrated chilled cast iron faces, and the screens are formed of bars of triangular steel to prevent choking.

The material to be pulverised is fed in at the periphery of the chamber and is at once struck and thrown against the lower screens through which the small fragments at once pass, the larger portions being thrown round against the upper bars and further reduced until they are small enough to escape through the lower screens, the grade of which determines the amount of reduction performed. Fibrous as well as granular materials can be pulverised in this machine which has, however, no grinding action, the beaters in every position being well clear of the stationary bars. The beaters make 4,000 revs. per min., giving a circumferential velocity of 262 ft. per sec.

1146. "Devil" disintegrator. Lent by the Hardy Patent Pick Co., 1894. M. 2381.

In this machine the material to be pulverized is subjected to a combined grinding and percussive action. Two renewable grinding rings are employed, one being secured to the casing and therefore stationary, while the other is attached to a disc which is rapidly revolved. Each ring is furnished with chilled cast iron teeth, arranged on their adjacent faces in concentric circles, with spaces between them. The teeth and spaces decrease in size towards the outside of the rings, and those on the fixed ring pass between the circles, of teeth on the revolving one. The clearance between the two rings can be adjusted while the machine is running, by a handwheel and screw which act upon the end of the revolving shaft. The materials to be granulated, or shredded, are introduced through a hopper into the centre of the machine. Wings on the revolving disc throw the material, by centrifugal action, between the teeth of the grinding rings, and the whole series must be passed before it escapes at the periphery, and so to the discharge orifice at the bottom of the casing. The teeth are largest where the rough material first enters, and get finer and closer as the fragments become smaller. The shaft runs at 900 revs. per min. giving a circumferential velocity of 74 ft. per sec.

1147. Parts of primitive stamp mill. Presented by F. W. Oldfield, Esq., 1905. M. 3409.

These stone shoes, with the corresponding twin die, are from the province of El Oro, in Ecuador, where they formed part of the primitive stamp mill for gold-bearing quartz shown in the attached prints. The construction is traceable to Spanish influence, and is believed to have been introduced about the 17th cent.; the mill shown was actually in use till 1880.

The battery consisted of two stamps, the shoes and dies being simply boulders of andesite picked from the river bed. The shoes are dressed roughly square and tapered to fit into the socket in the end of a stem of squared timber working between wooden guides. In the stem was a slot for an arm which acted as a tappet and was raised by four lifters cottered to an octagonal wooden shaft driven by an overshot water wheel. The lifters were arranged so as to raise the shoes alternately. The dies were roughly dressed to start the wear and were wedged in place with smaller stones. The mortar was formed by a wooden housing, the screen being a piece of board pierced with nine holes for plugs to regulate the height of discharge and hence the fineness of the crushing. The pulp from the battery flowed through a channel 12 ft. long by 15 in. wide, filled with blanket in 3 ft. strips; the coarser tailings were caught in a large hole and returned to the battery. The free gold and concentrates washed from the blankets were amalgamated in a "batea" or wooden dish.

The life of the shoes and dies was about 25 days. Each battery crushed in 24 hours, 400 to 600 lbs., chiefly of the soft surface oxidised ore.

1148. Model of stamps used in Saxony. (Scale 1 : 20.) M. 2623.

The cam-barrel is an oaken shaft connected to the axle of an overshot water-wheel. Of the stamp heads shown, two sets of three are for wet stamping—the general practice in preparing ores for concentration—whilst one set of three are for dry stamping, the stamps being used instead of rolls for rich silver or lead ores. The ore is supplied to each wet set from a hopper by a shoot which receives a jolting from a projection on one of the lifters; the water is supplied from a launder. The dry set is fed with ore by hand. The floor on which the wet heads work is of hard vein stuff

rammed between a framing of longtudinal bars; the dry heads work on a cast-iron anvil supported on wooden piles. The wrought iron heads weigh 300 lbs. and are fixed to square lifters of alder. Each stamp is lifted three times for every revolution of the wheel, the amount of lift being 14 in. for the wet, and 9 in. for the dry heads.

1149. Model of stamps used in Cornwall. Made by T. B. Jordan, Esq., 1842. (Scale 1 : 24.) M. 2621.

This shows the original arrangement of the stamps erected by Mr. J. Sims for crushing tin ore at Carn Brea mine, Redruth.

There were 72 stamp heads arranged in line, with the steam engine in the middle; the engine drove the cam barrels by a pair of clutches. The stamps were arranged in sets of three, divided from each other by upright posts, to which were attached thick oaken planks forming a closed box or "cofer," 20 in. deep. The bed was formed of hard quartz stamped in between walls of masonry to a depth of 18 in. The ore, previously broken into lumps of about 2 cub. in., was brought in wagons along an incline raised about 10 ft. above the ground, and delivered into bunkers whence it is fed into the cofers. Water run in with the ore carried off the fine stamped particles through perforated copper plates in front of the boxes, the holes being from ·025 to ·033 in. diam. The stamp heads were of white cast iron, socketed in the wooden stem and secured by two iron bands. Each head was lifted five times for every revolution of the engine. The cam-barrels were cast iron flanged cylinders bolted together.

1150. Model of stamps used in Cornwall. (Scale 1 : 6.) M. 2622.

This represents one set of four stamps at Par Consols tin mine, Bodmin. The lifters are of fir, and guided back and front by vees from the cross-bars of the framing. The shorter sides of the "cofer," as well as the front, are provided with discharging grates; the front grate, which is unusually large, measures 23·5 in. by 7 in. high. The weight of the stamp head was 644 lbs., the lift 10 in., and the number of strokes 50 per min. The amount crushed per head per 24 hours was about 17 cwt.

In more modern Cornish batteries the lifters are of wrought iron with the heads cast on; the tappets are also of iron, and, generally, five heads are placed in a box. The weight of the stamps has also increased to 900 or 1,000 lbs., and the number of blows per minute to 70 or 80, giving an average duty of one ton per head per 24 hours.

1151. Model of ironstone dressing machine. (Scale 1 : 12.) M. 2625.

This is a combination of stamps with a rising current separator, and was patented in 1855–6 by Mr. H. Mackworth as a means for freeing nodules of ironstone from attached clay. There are seven stamps arranged in two rows, all working on a cast-iron floor. The stamped ore is received in a conical tub, in which revolves a vertical stirrer, and is carried through by a current of water maintained by a force pump. The flow carries the shale to the top and discharges it, while the cleaned ironstone collecting at the bottom is raked out through a door in the front.

1152. Model of stamp battery. (Scale 1 : 10.) Made by Carl Schumann. M. 2626.

This is a German model of a timber-framed battery for gold ore, and resembles in many respects No. 1153, but four stamps are arranged in each mortar box, and the cams are single ended. The ore is brought in wagons, one side of which can be dropped so that the ore falls by a shoot into the mortar box.

1153. Model of stamps used in Australia. (Scale 1 : 16.) M. 2624.

The improvement seen in these stamps was first introduced in 1851 in California, and consists in an arrangement by which their heads are rotated so as to give a certain amount of grinding action and also to prevent irregular wear.

The heads are cylindrical and cast on to wrought-iron lifters; the tappets are small cylinders keyed to the lifters, and the cams act on their lower faces, so causing the heads to rotate through about 120 deg. at each lift. The ore is placed in a large hopper behind the stamps and fed into the boxes by two shoots, which receive a jolting motion. The stamped ore is washed away through a grating in front of the mortar-box and passes over a shallow trough containing mercury; it then passes over a series of inclined tables broken into low steps and covered with coarse serge blankets.

The stamps used in the Clunes gold mines, Australia, in 1864, had Bessemer steel heads weighing 784 lbs., struck 76 blows per min., and crushed 54 cwt. of ore per 24 hours.

1154. Model of stamp battery. (Scale 1 : 16.) Lent by R. E. Commans, Esq., 1891. M. 2397.

This represents a modern form of gravitation stamp battery, having two sets of five stamps. It consists of a timber framing strengthened by iron tie bolts, although wrought iron frames are sometimes adopted. The stamps are lifted, frequently in the order 1, 4, 2, 5, 3, by double-ended cams, keyed to a horizontal shaft which rotates in bearings bolted to the framing. Each shaft carries five cams, and is driven independently by belting from a counter shaft running along the back of the battery. The ore is fed from hoppers into the mortar boxes, which are furnished with steel dies to receive the blows of the stamps. The ore when pulverised is washed out through the front screens by a stream of water, about 270 cub. ft. being required for each ton stamped. Free gold contained in the ore is caught in front of the mortar boxes on copper plates, coated with quicksilver, which retains the gold by amalgamation.

The weight of a single stamp varies from 500 to 900 lbs., according to the hardness of the ore to be crushed; it makes 80 to 90 drops of 6 in. to 10 in. per min., and crushes from 1·5 to 4 tons of ore per 24 hours; smaller machines are made for prospecting purposes.

1155. Model of stamp battery. (Scale 1 : 8.) Lent by Bertram Gray, Esq., 1898. M. 3031.

This represents a modern five-head battery, and shows, in addition to the other details, the massive timber foundation on which the mortar box, which receives the blows of the stamp, is bedded. The timbers of this foundation are bolted and dowelled together, but are independent of the main framing, as they rest on a block of concrete at a considerable depth below the ground level. The other arrangements are very similar to those shown in No. 1154.

The cam-shaft is driven at a speed of about 95 revs. per min., by a belt passing over a wooden pulley built on a metal centre. Each stamp weighs from 450 to 1,300 lbs. and has a drop of 7 to 8 in.; the guides for the stamp stems are formed in adjustable hard-wood blocks. To throw any stamp out of action a row of "jacks" or levers pivoted on a shaft behind the stamps is provided; any jack when swung forward will catch under its tappet collar when in the highest position, thus preventing that stamp from falling. Each tappet collar is secured to its stem by a key, which is tightened up by two or three transverse cotters.

1156. Model of stamp battery. (Scale 1 : 6.) Lent by the Sandycroft Foundry Co., Ltd., 1899. Plate III., No. 1.
M. 3074.

This represents a modern form of gravitation stamp battery of 10 heads, used for gold milling. The stamps are, as is usual, in sets of five, quite independent. The description refers to one such set.

The framing is of the "high-bank" type, *i.e.*, the ore bin is incorporated with the stamp framing; it is of pitch pine held together by iron tie rods. The ore is supplied from a hopper to each set of stamps through a sliding door actuated by a rack and hand wheel and slides down a shoot on to an automatic feeder—an improved form of that originally introduced by Joshua Hendy. It consists of an inclined plate which is caused to revolve by an adjustable friction feed motion obtained from a bumper rod struck by a tappet on the middle stamp stem when a deficiency of ore below it causes it to fall low enough. The fixed vanes resting on the plate sweep off the ore into the mortar box.

The stamps are guided in removable hard wood bearings arranged on the front of the framing. They have iron stems and steel shoes striking on steel dies embedded in a concrete base below; tappets on the stems are acted on by double-ended steel cams fixed by Blanton's keys (*see* No. 1158) to a horizontal shaft on bearings in the framing. The stamps are lifted in the order 1, 3, 5, 2, 4, which is that most favoured on the Rand. The cam shaft is driven by belting from a counter-shaft below the floor, By releasing a jockey pulley toggle tightening arrangement, any set can be independently disconnected. A row of "jacks" is provided (*see* No. 1155). The mortar box is made of cast iron of trough section with a screen of wire cloth in front through which, as it is pulverised, the ore is washed by a stream of water from a supply pipe on the frame. The pulverised material flows down troughs lined with copper plates coated with mercury which retains the gold by amalgamation. These are often succeeded by blanket tables (not shown).

The weight of each stamp head varies from 800 lbs. to 1,300 lbs., and the height of the lift from 6 in. to 9 in. The amount crushed varies from 3·5 tons to 5 tons per stamp per diem, according to the nature of the ore and the mesh of the screen used.

A photograph on the opposite wall shows a double row of these batteries erected at a mine in South Africa.

1157. Model of mortar box for stamp mill. (Scale 1 : 6.) Lent by Messrs. Fraser & Chalmers, Ltd. 1907. M. 3472.

The mortar box is constructed so that the front is removable, as patented in 1901 by Mr. D. B. Morison, for convenience in obtaining ready access to the interior, particularly for renewing the dies, shoes and lining; the last named are usual in modern practice. The lining and fittings shown are of the kind patented in 1904 by Mr. D. A. Bremner. The linings extend from the hopper mouth to three sides of the interior; they are built up in sections for convenience in handling, and have wearing plates riveted to the front. For checking the ejection of "pulp" a canvas screen is hung on the inside of the hopper. The front of the mortar box is closed by a pressed steel plate which is hung from a crane jib so that it can swing out of the way. The front plate and the screen are held in place by nuts with handles whose weight is adjusted to act under vibration so as to tighten the nut.

1158. Models of cam fastenings. (Scales 1 : 4 and 1 : 8.) Lent by Messrs. Fraser & Chalmers, Ltd., 1907. M. 3473.

This method of keying a wheel, &c., to a shaft so that it is capable of being easily removed, was patented in 1893-7 by Mr. E. A. Blanton. It has been widely adopted for fixing cams to shafts of stamp mills as shown; it has also been applied to the transmission of power.

Two forms are shown. In the first a tapered liner embracing part of the shaft is pinned to it to prevent relative movement between them. A corresponding recess in the boss of the cam, usually cut in a relieving lathe, fits over the liner, and a slight rotative motion causes a wedging action. To transmit motion in the reverse direction the liner and cam must be placed on the shaft in the opposite sense. In the second case a number of eccentric projections or relieved surfaces are formed on the shaft to fit corresponding recesses in the bosses of the cams. In this case the number of recesses is a multiple of the number of the cams so that they can be altered to lift in the sequence that is found most suitable, while they will always assume the correct angular position to one another.

1159. Model of riffle for sluices. (Scale 1 : 4.) Presented by H. Bauerman, Esq., F.G.S., 1881. M. 1590.

This riffle was patented in 1881 by Mr. W. H. Howland, to take the place of the ordinary riffle bars in the flume or sluice carrying auriferous material or sulphides from a stamp mill. It is made of cast iron in sections, each consisting of an anticlinal ridge with grooves on both slopes parallel to the direction of the current. At the ridge and also at the foot of the tail slope are troughs to hold the mercury. The sections are placed, breaking joint, in the flume to produce eddies which assist the separation of the particles of gold and their collection by the mercury.

SIZING APPLIANCES.

1160. Model of sizing machine used at Freiberg. (Scale 1 : 8.) M. 2586.

This is an arrangement of flat rectangular sieves for classifying the ore passed through a crusher. The sieves are of uniform breadth, but the length and also the mesh of the wire gauze decrease from above downwards; the sieves are suspended from one another by links at an angle of 11 deg. Each sieve receiving a jolting motion from a vertical cam-shaft, the return movement being given by gravity. The ore is delivered from a large hopper on to the topmost sieves and the jolting causes all particles larger than the mesh to fall over the fronts into their appropriate bins. The number of classes produced is five or one more than the number of sieves.

1161. Model of Saxon sizing trommel. (Scale 1 : 6.) M. 2587.

This is a plain horizontal drum for sizing the sands from a stamp battery. The drum is of light iron-work 4 ft. diam. by 5·5 ft. long, divided into three lengths in the ratio 2 : 2 : 1 and covered with wire gauze; the first has 150 holes to the sq. in., the second 75, and the third 30. The surface is cleaned by jets of water. The drum makes 7 revs. per min., and as its axis is not inclined, a screw conveyor is introduced to move the ore along.

Trommels of this character are now very generally used for sizing ores; the wire cloth, for all but the smallest sizes, is replaced by perforated plates and each trommel separates but one size. If the drum is cylindrical, the axis is inclined; but if conical, the axis is horizontal; by these arrangements conveyors are dispensed with.

1162. Model of rotary screen used in Saxon amalgamation works. (Scale 1 : 8.) M. 2714.

The ores intended for amalgamation after having been roasted with salt and iron pyrites in the reverberatory furnace (No. 1248) are sifted through an eight-sided drum sieve contained within the hutch, and having a slight inclination; the upper bearing of the axle is cylindrical, while the lower one has a cam-wheel attached to it which rests on a step-shaped bearing giving a slight lateral jerking motion to the sieve as it revolves. The ore is fed

through an inclined trough, which receives a jerking motion from a cam-wheel and lever acting against a wooden spring beam. The gauze covering the upper part of the sieve is of double thickness, and separates a sufficiently fine-grained material for grinding (*see* No. 1140); the bulk of the stuff passing through the single thickness is again sifted through a finer sieve; the coarser lumps are returned to the calciner to be roasted with a fresh addition of salt.

1163. Model of vibromotor screen (working). (Scale 1 : 5.) Made from drawings supplied by the Hardy Patent Pick Co., 1906. M. 3467.

The vibromotor, patented in 1892–3 by Mr. W. W. Beaumont, and since considerably modified, is a means of giving gyratory motion to an object such as a screen by the action upon it of an unbalanced force when the whole system is freely suspended.

A weight attached to an arm keyed on a spindle is rotated from overhead by a flexible shaft or by an electric motor. The spindle, in common with every other part, would revolve round the centre of gravity of the whole were its path not modified owing to the fact that the bearing in which it rotates is attached to the screen. The resultant gyratory motion which is thus impressed on the whole system may be modified in character and amplitude by varying the position of the weight on the arm and the load on the screen. It is claimed that the whole of the work transmitted through the spindle, neglecting friction, is used within the system, so that no vibration is transmitted to the supporting framework. Screens on this plan can, therefore, be driven at a much higher speed than can screens driven by the crank, cam, or eccentric method.

The screen shown is for grading coal into three sizes. It is constructed entirely of metal, and suspended by wire ropes held in clips. The bearing on the screen is of large diameter, and the revolving weight is carried by a ball bearing.

CONCENTRATION.

1164. Model of Cornish keeve or dolly tub. (Scale 1 : 4.) Presented by Capt. W. Teague, jun., 1882. M. 2582.

Model of Saxon keeve. (Scale 1 : 8.) M. 2912.

This appliance, consisting merely of a tub in which the finely divided ore is stirred and then allowed to settle, is specially used for the final concentration of lead and tin ore.

In the Saxon keeve a stirrer with four paddles worked by hand is used.

In the Cornish keeve the stirring (*tossing*) is done by paddles on a vertical axle rotated by a bevel gear and clutch from a power shaft. The settling in classified order (*packing*) is assisted by taps on the outside of the tub from a hammer continuously tripped by a cam on the shaft; the water is drawn off and the deposit scraped off layer by layer.

1165. Hand sieves. M. 2601–2.

These Cornish sieves, formerly used for dressing tin ore, show the simplest form of jigging appliance. The charge of ore is placed in the sieve, and is given a series of short jerks in a tub of water. The heavier ore settles to the bottom of the sieve. One of the sieves is 18 in. diam. by 5 in. deep, and has a bottom of iron wire gauze with holes ·125 in. square; the other is a tub 20 in. diam. by 5·5 in. deep, and has a bottom of copper plate perforated with holes ·05 in. diam. and about ·4 in. pitch.

1166. Model of hand jigging machine. (Scale 1 : 8.) M. 2603.

This is a simple form of jig, once much used in Cornwall for concentrating copper ores. The sieve is a rectangular box or "hutch" 57 in. long, 24 in. broad, and 10 in. deep, supported from the short arm of a compound lever by two vertical iron bars. A square wooden pipe supplies clean water over one side of the hutch, and the muddy waste water is carried off on the opposite side. The hutch measures 90 in. long 43 in. broad, and 45 in. deep. An iron scraper is used to remove the contents of the sieve, which is usually classified into three parts; the uppermost is thrown away, the middle requires further treatment, while the bottom is clean ore fit for sale. The fine stuff passing through the sieve collects in the hutch, and is subsequently treated on the round buddle or other slime washing machine.

1167. Model of Cornish jigging machine. (Scale 1 : 12.) Received 1842. Plate III., No. 4. M. 2605.

A water-wheel, 14 ft. diam., with an external spur ring, drives two cranks that give a jigging motion to two levers from which the sieves are suspended; four slots in the suspending links enable the sieves to be raised independently by a hand lever for emptying. In other respects it resembles No. 1166.

1168. Model of hutching machine. (Scale 1 : 12.) Presented by T. Sopwith, Esq., F.R.S., 1851. M. 2604.

This machine was made by Mr. J. Hetherington, and used at the Allenheads mines, Northumberland. The sieve is formed of parallel rods, and is suspended by vertical links from counterbalanced levers that are kicked by 14 pins on the faces of two revolving wheels. The shaft can move longitudinally so as to draw the pins out of gear with the levers. A small winch is fitted for use in lowering the sieve into the hutch after emptying.

1169. Model of jigging machine used in Saxony. (Scale 1 : 8.) M. 2606.

In this machine the sieve is fixed and the water moved, a modification which appears to have been first introduced into Cornwall by Mr. Petherick in 1831, and is now in very general use, especially for coal washing.

The machine represented was constructed for dressing argentiferous lead ore. It consists of a wooden hutch divided into two square compartments, in one of which is a zinc plate perforated with holes about ·125 in. diam., and in the other a plunger 27 in. square, attached by a rod to a wooden lever, which is raised by a revolving eccentric and falls by the action of the weight of a loaded box. The crushed ore is placed on the sieve and subjected to the alternating currents of water, forced through it by the plunger, whose stroke is 3 in. An opening in the partition dividing the compartments is provided with a sliding door for regulating the current; this is closed when filling or cleaning the sieve. The launder is for running off the dirty water.

These machines were generally arranged with a sieve on each side of the plunger, so that one might be cleared and refilled while the charge on the other was in process of concentration.

1170. Model of jigging machine. (Scale 1 : 12.) Presented by J. W. Arundell, Esq., 1863. M. 2592.

This jigger is similar to No. 1169, but the compartments are the legs of a cast-iron U-tube of rectangular section; the sieve is fixed in one leg and the plunger is worked by a cam in the other. The "hutchwork," or fine stuff which passes through the sieve, is discharged through a hole at the bottom into a settling pit; the waste water is replaced by a pipe, and there is the usual sliding partition for separating the two compartments.

1171. Model of jigging machine. (Scale 1 : 3.) Presented by Ministerialrat P. von Rittinger, 1862. M. 2608.

This is a continuous jigging machine, with the suspended sieve reciprocated horizontally only; vertical motion is given to the water by a lift pump.

A crank pin moves the bucket which contains four leather-faced iron clacks, and the bottom of its box has four similar foot-valves; the water passes through the sieve and returns to the hutch through the foot-valves. The ore is fed in along an inclined trough, vibrated by a cam which also causes the sieve to oscillate, both being returned by adjustable spring beams. The ore, in addition to being sorted by the water, is worked forward by the shaking motion of the frame. On arriving at the end of the principal sieve, the deposit is cut horizontally into three layers by the edges of three sorting sieves; the lowest takes the best ore which passes into the first box No. 1; the second quality into box No. 2, and the lightest is discharged by the top sieve into box No. 3; the fine stuff passing through the sieves is removed through two mud-holes at the bottom of the hutch.

An actual machine with a pump of 3 in. stroke making 75 revs. per min., treated 1·5 tons of ore per hour, and required ·75 H.P.

1172. Model of Remfry's jigging machine. (Scale 1 : 6.) M. 2578.

This is a continuous jigging machine, and represents a type much in use for treating ore from ·25 in. down to ·04 in. The mesh of the sieve is slightly greater than the size of the ore, but is reduced by a bed of clean ore of larger grain first placed on the sieve.

The machine consists of a rectangular water box with a semi-circular bottom, divided into three similar double hutches. In one compartment of each hutch is a fixed sieve, and in the other a piston reciprocated by an eccentric on an overhead belt-driven shaft. The stroke of the piston can be varied from 3 in. to zero, and the number of strokes is from 80 to 300 per min., according to the fineness of the ore. The ore is delivered from a classifier to one end of the line of sieves, and as each sieve is at a slight inclination and a little below the previous one, the ore travels forward. The heaviest particles sink through the bed into the first hutch and the lighter ones into the second and third, while the lightest pass over the end into a tank as tailings. There is a hand wheel to each hutch for emptying it into a settling tank below.

Specimens of galena produced by each hutch are shown.

1173. Model of coal-dressing machine. (Scale 1 : 8.) M. 2607.

In this apparatus, patented in 1856 by Mr. H. Mackworth, the coal to be cleaned is delivered by a shoot into a separating chamber containing water, and having a floor of perforated plates, through which the water is continually being jerked upward by a large single-acting circulating pump contained in the machine. The separator is divided by a nearly vertical perforated plate, and is surmounted by a perforated, travelling, endless apron provided with projecting blades. Owing to the motion of the water the heavy shale alone arrives at the bottom of the separator, where it collects in a chamber, while the coal is divided into two classes by the vertical screen, and carried to the delivery shoot by the apron, through which the water passes on its way back to the pump. The fine dust is drawn away from the entering coal by a fan. which projects it upon the wet cleaned coal, so that it does not pass through the water.

1174. Model of pointed box classifier. (Scale 1 : 12.) Presented by J. W. Arundell, Esq., 1863. M. 2588.

This is a modification of an arrangement introduced by Rittinger in 1844, in which classification is effected by a series of settling boxes, hanging from the floor of a shallow trough that is conveying the stuff from the stamps. The bottoms of the boxes are formed as hoppers to facilitate emptying. These separators are generally used for classifying ore which is too fine to be successfully sized by sieves.

In the modification shown, which was patented in 1862 by Mr. Arundell, the slime is first mixed with water and passed through a drum sieve of perforated copper, into a launder 13 in. broad, at the upper end of which it mixes with a stream of clean water. The pointed boxes, four in number, are of the full width of the launder, but of increasing length; the heaviest particles are deposited in the first box, while the lighter ones pass on to the second box, and so on. The fine stuff which passes to the fourth box is run to waste.

1175. Model of conical slime separator. (Scale 1 : 12.) Presented by J. W. Arundell, Esq., 1863. M. 2589.

This is a rising current apparatus, patented by Mr. Arundell in 1862. Like No. 1174 it is used rather for classification than for concentration. A machine differing slightly from this was introduced in 1859 by Mr. Borlase into the lead mines of the north of England.

The machine has an inverted conical plug within a conical hopper, the two leaving between them a passage of uniform area, so that the rising current of water has a constant velocity. Above the plug is another conical hopper, which acts as a distributor for the slimes introduced above it. The current is so regulated that the bulk of the light earthy material is carried over the top by the current, while the heavier particles are discharged at the bottom of the conical case.

1176. Model of slime-washing table. (Scale 1 : 12.) M. 2595.

This is an old machine, formerly used in Saxony, but now displaced by the rotary table. The table is 14·5 ft. long by 3·75 ft. broad, and is placed at a slight inclination that is adjustable by wedges. The surface is of hard wood, planed, and then slightly roughened by sulphuric acid. The slime, mixed with water in a box and screened, was delivered at the upper end of the table on a head-board provided with studs for distributing the stream uniformly. The flow continued until a layer ·125 in. thick was formed over about three-quarters of the surface, when the supply was stopped and a gentle current of water turned on, which carried the lighter impurities over the end of the table into the waste launder. The lowest third of the material on the table was swept by a movable launder into one division of the ore box below; the middle third was swept into the other division, first passing through the sieve; while the top third, by reversing the launder, was swept with the aid of water into the good ore box below the table. The cycle of operations took about 20 min.

1177. Models of Cornish slime frames. (Scale 1 : 6.) Made by J. T. Letcher, Esq., 1892. M. 2484.

This shows a double set of self-acting slime frames, as used in tin-ore dressing, for treating the tailings from the buddles, and so recovering any heavy particles not already separated.

The tailings or slimes are brought in a long trough running along the top of the machine, and another trough in front brings a supply of water to be used in flushing the frames. The frames are furnished with lozenge-shaped spreaders, which distribute the slimes uniformly over the slope. Down these inclined surfaces the slimes gently flow, the heavy tin-ore particles settling on them, while the lighter refuse flows into a trough below.

The upper part of each slope is crossed by a water-trough so pivoted that, when filled to a certain height, the time being regulated by the water supply at the side, the trough overbalances and the sudden discharge of its contents sweeps the deposited ore down the slope. This overbalancing of the trough also opens the cover of a trough at the base of the slope, and at the same time shields the ordinary waste trough from receiving the tin ore. In one section of the model the slopes are divided into two steps, but the greater portion of the ore is deposited on the upper ones. The balanced water-troughs are replaced in position by hand levers, as shown in the other section of the model, but in the first-named section, a small box at right angles to the trough fills with water after the balanced trough has tilted and brings it back again into its initial position, so rendering the machine completely automatic. The scoop wheel between the two frames is to lift the slimes from the first up to the level necessary for treatment by the second, and the small revolving screen here introduced is to remove any exceptionally large material. After leaving the frames the slimes pass over several settling tanks before being finally rejected. The deposited material in the tanks is afterwards dug out and re-treated.

1178. Model of Brunton's belt. (Scale 1 : 24.) Presented by W. A. Thomas, Esq., 1871. M. 2583.

This arrangement, used at the Devon Consols mines, was patented by Mr. William Brunton in 1844. The fixed table of the Cornish slime frame (*see* No. 1177) is replaced by an endless canvas belt at a slight adjustable inclination reinforced by cross-laths of wood on the underside. At a third of its length from the top is a head-board, which delivers the slime on to its surface. Near the head a stream of water is delivered, and runs down the belt, carrying the lighter particles with it, while the heavier particles stick to the belt, which travels continuously in a direction opposite to that of the stream, until they are washed off while passing through a tank of water below. The tailings run off the belt into a box on wheels, by which they are removed, or may be carried off through a trough.

The modern Frue vanner greatly resembles this machine, but in it the canvas is replaced by an india-rubber belt with raised edges which, in addition to travelling up-hill, is given a side-shake.

1179. Model of Schell's rotating table. (Scale 1 : 12.) Presented by D. Zenner, Esq., 1860. M. 2597.

This shows the original form of the rotating table invented by Herr Schell, of Clausthal, in 1854. It consists of a convex wooden table fixed to a vertical shaft rotated by worm gearing from a water-wheel (not shown). The slime is stirred with water by paddles in a box, which has a coarse grating at the inlet and a finer one at its outlet to the launder. The slime is distributed on to the table by a central ring launder, one-fourth of its length delivering slimes and the remaining three-fourths jets of clean water, while a special launder furnishes additional water jets.

The classified ore reaches the circumference at different points, the lightest first. To receive it there is an annular launder divided into sections of different lengths, each with its own discharge pipe. The greatest section of this launder receives tailings, and the shortest is reserved for the concentrate, for the removal of which reciprocating and fixed brushes are necessary to assist the water. This machine showed a great saving in time and labour when compared with the old shaking table.

1180. Model of Saxon rotating table. (Scale 1 : 12.) M. 2598.

This model shows a modification of Schell's table (*see* No. 1179), erected in 1855 at the Himmelsfürst mines in Saxony; it is driven by shafting and worm gearing from an overshot water wheel 6 ft. diam.

The slimes, mixed with water in a box, are delivered at one point only, while the ring launder, extending two-thirds round the shaft, brings the

wash-water which flows over a spreading cone before reaching the table. The launder at the circumference has no partitions, but its bottom slopes in opposite directions; the tailings are delivered into a single pit, and the classified concentrate into a double one.

1181. Model of concave rotating frame. (Scale 1 : 6.) Presented by Ministerialrat P. von Rittinger, 1862. M. 2600.

This machine was first introduced in 1860 by Herr Rittinger, at Chemnitz, in Saxony, for dressing poor slimes. It is a shallow concave cone, 16 ft. diam., attached to a vertical shaft rotated by worm gearing. The surface is divided into 32 segments by strips of wood ·75 in. high. The slimes are mixed in the slime box by a rotary paddle and then passed to the 11 fixed head-boards, occupying an arc of 320 deg. above the frame; of these boards, the spreaders Nos. I., III., V., and VII., deliver slime, while the alternate ones II., IV., VI., and VIII., deliver water, as do the three hinder ones, which are smaller, and have their outer edges cut into a series of steps.

Supposing the ore under treatment to contain galena with pyrites and matrix, the action would be as follows: as the frame revolves, a particular segment receives a layer of slime from No. I. head-board; water from No. II. board then carries off the lighter particles, and leaves the heavy ones on the frame; the segment receives more slime from No. III., which is washed by water from No. IV., and so on till the segment has passed No. VIII. It then retains a concentrate of galena and pyrites which is cleaned off by water from the three hinder boards, which deliver streams of increasing force. The clean lead ore remains, and is washed off by a jet of water from a pipe. Each of the segments of the frame has, at its lower end, a square vertical wrought iron shoot for discharge.

Experiment proved that the best results were obtained when the speed was 6 revs. and ·66 cub. ft. of slime or ·93 lbs. of solid ore were being fed on to the table per minute.

1182. Models of convex rotating tables. (Scale 1 : 12.) Presented by J. W. Arundell, Esq., 1863. M. 2590.

These two models show a modification patented by Mr. Arundell in 1862. The rotating table is of cast iron, driven by bevel gear. Slimes from the pointed box classifier (No. 1174), are introduced at one point only; the washing water is supplied by a perforated annular pipe, connected to the main supply at several points by cocks so that the force of the jets may be varied as desired, and perforated tangential pipes are used for flushing off the concentrate. The tail launder is divided into three parts, covering respectively arcs of 30 deg., 90 deg., and 240 deg., each with its own discharge pipe and catch-pit.

1183. Models of concave rotating tables. (Scale 1 : 12.) Presented by J. W. Arundell, Esq., 1863. M. 2591.

This form of table was first introduced in Rhenish Prussia in 1861, and is sometimes known as a funnel frame. Except that the flow of slime and water is from the outer to the inner circumference, the machines are similar to the adjacent convex tables (*see* No. 1182).

1184. Model of Saxon shaking table. (Scale 1 : 24.) Presented by Thomas Weaver, Esq., F.R.S., 1855. M. 2609.

This model represents a form of shaking table in use at Freiberg in 1792. This type of machine was once very extensively employed, and is still used to some extent for treating fine stuff, but generally has been replaced by the buddle. The model differs but slightly from the later pattern (*see* No. 1185).

1185. Model of Saxon shaking table. (Scale 1 : 16.) Presented by John Taylor, Esq., F.R.S., 1842. M. 2610.

The machine has a rectangular table about 14 ft. by 6 ft., with raised edges on the sides, and is supported in an inclined position by four chains. The two chains at the lower end hang vertically from a horizontal axle, by which the slope of the table for the various grades of ore can be adjusted. The shaking motion is communicated by a bell-crank lever, the arm of which is adjustable, and is acted on by cams on a revolving horizontal shaft (not shown).

The stuff is mixed in a slime box and distributed by a head-board over the table where, under the combined influence of the shaking motion and a stream of clean water, the lightest particles are removed. The work is continued till a layer of about 6 in. thick has accumulated, when the table is stopped and the classified deposit shovelled off in sections.

The stroke varies from 7·5 to 9·5 in., and the number is from 30 to 40 per min. for coarse sand, and 35 to 45 for finer slimes; the volume of water required is from 8 to 9 times that of the ore in the first case, and from 1·5 to 2·5 times in the second case.

1186. Model of shaking table. (Scale 1 : 12.) Received 1842. M. 2611.

This table, introduced by Mr. Robert Stagg in 1828, was used at the Northumberland lead mines of the London Lead Co.

There are two paddle wheels for more thoroughly mixing the slimes, and the front pair of chains is adjustable by long screws; otherwise the apparatus is similar to No. 1185.

1187. Model of continuous shaking table. (Scale 1 : 6.) Presented by Ministerialrat P. von Rittinger, 1862. M. 2612.

This shows the arrangement adopted in the first experimental machine made by Herr Rittinger in 1858. The table is suspended by four links, and receives a jolting motion, at right angles to the flow of the washing water, from a cam, the return strokes being given by a wooden spring beam. The slime is introduced from a mixing box over a distributing board, and a stream of clear water over another. The heaviest particles of ore, being but little affected by the downward flow of the water, move to the left under the jolting action, while the lightest ones are carried straight down; particles of intermediate densities follow paths varying in inclination with the edge of the table so that the richest ore passes over at the left-hand end and the seconds and waste at the lower edge. The table is 6 ft. long by 3 ft. broad and has a stroke of 2 in. In practice, the difficulty of discharging the ore sideways at the low velocity required led to a modification in the construction, by which the discharge was confined to the lower edge and the output increased.

1188. Model of shaking table. (Scale 1 : 4.) Lent by The Wilfley Mining Machinery Co., Ltd., 1907. Plate III., No. 5. M. 3484.

The action of this continuous ore separator, like its prototype the Rittinger table of 1858 (*see* No. 1187), is dependent upon rapid oscillation in a direction at right angles to the flow of the pulp. The appliance was introduced in 1895 by Mr. A. R. Wilfley, and has been modified in construction since; the model represents the latest form.

The table is trapezoidal in plan, 15·8 ft. long, 6 ft. wide at the head, tapering to 5 ft. wide at the tail end; to avoid warping, it is constructed of red-wood strips laid diagonally, ribbed with wood-filled pressed steel stringers below. Linoleum, having proved to be the most satisfactory working surface, is the covering used; lengthwise on this are nailed wooden riffles 1·37 in. apart, centre to centre. These vary in length from about 4 ft. at

the feed side to the full length of the table at the discharge side; also they taper in depth to a feather edge at the tail end. The table rests on rockers supported by transverse beams on a longitudinal timber balk; the beams can be tilted to the necessary angle by cams actuated by bevel gearing and a hand wheel.

The table receives adjustable motion lengthwise from the toggle joint straightened by an eccentric driven by belting; the speed of the table consequently is greatest when near the end of the stroke, so avoiding lost motion of the ore particles. The slime or pulp is fed without splash from a trough attached to the table along the higher side; on the same side but fixed to the framing is a trough for the wash water.

The particles acted on by the water, shaking, and gravity follow a curved path modified by the riffles which assist in detaining the heavier particles while allowing the lighter ones to be washed over. At the lower tail corner the middlings discharge into an inclined trough whence they are raised for further treatment by a scoop wheel actuated by gearing from the driving pulley, or they may go to another table. The rest of the discharge consists of tailings.

The speed of the table would be 240 double strokes of ·75 in. per min.; the power required is 1 H.P. The capacity at this speed, depending on the nature of the ore, is stated to be from 15 to 30 tons per 24 hours with a consumption of 200 gals. of water per hour.

1189. Model of Saxon hand buddle. (Scale 1 : 24.) M. 2909.
Model of slime trunking machine. (Scale 1 : 10.)
Presented by John Hunt, Esq., 1851. M. 2593.

The hand buddle or trunk is a long rectangular box with a sloping bottom and an end provided with a vertical row of discharge holes. The ore is placed on a raised part at the back of the trunk and worked with a spade in an entering stream of water, which carries away the slime and deposits the heavy particles along the floor at distances corresponding with their "equivalents." As the deposit increases, the overflow orifice is raised; the deposit is finally removed in sections.

The larger model represents a machine used in Brittany for dressing waste from some old workings. It has a distributing sieve, with holes ·06 in. diam., particles remaining on which are jigged. The trunk is 9·5 ft. long, 4·5 feet wide, 2 ft. deep, and has its floor inclined at 8 deg.

1190. Model of slime trunking machine. (Scale 1 : 12.)
Presented by M. Attwood, Esq., 1854. M. 2594.

This arrangement was introduced in 1849 by Mr. Attwood, at the lead mines of Alston Moor, Cumberland, and consist of three trunking machines and a dolly tub.

The slime is thrown into a box into which clean water is also delivered, and is there subjected to the action of revolving blades which break it up. After mixing, the material is screened through a curved perforated plate, and the refuse swept off into a launder. The fine stuff, after undergoing a further mixing by a second paddle wheel, is delivered on to an inclined table where it meets a stream of clean water, and falls into one of the rectangular tanks, which have their floors inclined at about 2 deg. to the horizontal. The richest ore from the trunks is prepared for market in the adjoining dolly tub (*see* No. 1164); the stirring paddle can be lifted vertically in guides out of the tub which can then be run out on rails; the hammer is on a horizontal rod driven by cogs. The whole of the apparatus is driven by a small overshot water-wheel.

1191. Model of sweeping table. (Scale 1 : 12.) Made by Herr Carl Schumann. M. 2585.

This modification was devised by Mr. Okladine in 1854 for gold-washing in Siberia. The wash-dirt is delivered, suspended in water, on to a short

table inclined at 10 deg., upon which the heavier materials are deposited, while the lighter ones pass off with the water. This deposit is subjected to the action of three sets of brushes, which make 25 upward sweeps per min.; during the down strokes the brushes are lifted above the table by hinged curved plates, and so have no action. At every sweep the deposited materials are re-exposed to the action of the down-flowing stream, so that more of the light matter is washed off and the concentrate therefore improved. The machine is stopped at intervals and the concentrate cleared off the table for further treatment.

The brushes depend from a frame, reciprocated by a crank and carried by rollers that rest on the main framing; in the path of the rollers are four curved plates which act as inclines only on the down stroke.

Beyond the sweeping table is a stepped amalgamation table, on which the material is stirred by rakes actuated similarly to the brushes. The tailings from this pass into a shallow pan fitted with a revolving agitator, by which the lighter materials are kept in suspension so that they pass off with the water.

1192. Model of Cornish round buddle. (Scale 1 : 6.) Presented by John Taylor, Esq., F.R.S., 1851. M. 2596.

The round buddle, first used in Cardiganshire, was subsequently employed in Cornwall for dressing poor copper ores; the example shown is from Tywarnhaile Mines.

It consists of a convex wooden floor about 15 ft. diam., in a shallow pit. At the centre is a cone, which serves both as a spreader and as a footstep for a vertical shaft with two arms, carrying brushes (*missing*). The vertical shaft is driven by an inclined shaft on which are projecting knives working in a cylindrical slime mixer followed by a drum screen with 8 holes to the inch. The refuse from this screen is discharged by the vertical shoot on to the edge of the buddle whilst the slimes pass by a launder to a funnel at the centre, whence they flow over the spreading cone on to the inclined floor. The heaviest particles settle first, while the lightest escape at the circumference through holes in a sluice board provided with plugs at different heights. The brushes prevent the formation of gutters on the surface; they are counterbalanced by cords over pulleys to adjust them to the continually varying slope. When the deposit has accumulated to a depth of 6 to 12 in. it is dug out in 2 or 3 concentric rings of graduated richness,

At the present day the spreading cone is made of cast iron, 4 to 6 ft. in diam., 6 or 8 arms are used, the slope of the floor is 6 or 7 deg., and the number of the revolutions of the brushes is about 6 per min.; 1·5 to 2 tons of stuff are treated per hour.

1193. Model of concave buddle. (Scale 1 : 12.) Received 1865. M. 2599.

This form was introduced by Mr. E. Borlase in 1858, and differs from the last mainly in being concave. The slime pan is of cast iron, with six launders to deliver the slimes to the circumference, whence they flow towards the centre where the tailings escape, whilst the richest portion of the ore deposits itself near the edge. A central shaft rotated by worm gearing carries round six brushes and by gearing rotates a stirrer in the slime box.

1194. Model of buddle and jigging machine. (Scale 1 : 24.) Presented by W. A. Thomas, Esq., 1871. M. 2584.

This represents an arrangement used at the Devon Consols mines. The buddle is similar to No. 1192, and the jigger is of the original type with the sieve moved up and down in a hutch. It is counterbalanced, and can be worked by hand, but both machines are connected to a power-driven shaft.

1195. Buddle scraper. Presented by H. Rosales, Esq., 1874.
M. 2581.

This form of scraper for a buddle was in use at the Walhalla Gold Mines, North Gippsland, Victoria. It is of wood, but has along the edge a strip of india-rubber backed with iron, thus resembling a squeegee.

1196. Model of Saxon barrel amalgamator. (Scale 1 : 12.)
M. 2705.

The process here represented is quite obsolete, but its machinery is interesting as forming a link between that of the old Mexican process (*see* No. 1142) and the modern system of pan amalgamation.

The silver ore, previously finely ground between millstones (*see* No. 1140) and then roasted with salt in a reverberatory furnace, was delivered to hoppers seen in the upper part of the model. Portions were from time to time then charged in to the wooden barrels seen beneath, with a little mercury and some water, together with metallic copper or iron, usually the latter in the form of old cannon balls. The barrels were of oak, bound with iron and mounted on horizontal axes about which they were rotated by gearing by means of a water-wheel. When charged, the filling hole was closed and the barrel rotated for 24 hours at about 22 revs. per min. The resulting mixture of mud and amalgam was drawn off from the barrel and the bulk of the fluid amalgam diverted; the remainder was conducted through a grid (not shown) to strain off pieces of iron, and then down to the settling tank seen at the base of the model. Here it was stirred gently with much water by the rakes that were attached to the slowly rotating vertical shaft, and after a period the liquid was drawn off from the top in successive layers. Finally, the residue of the amalgam was collected from the settling tub and distilled; the purer amalgam withdrawn at the first was distilled by itself (*see* No. 1242).

1197. Model of leaching plant. (Scale 1 : 24.) M. 2697.

This represents a plant for the extraction of silver from argentiferous copper regulus by either Ziervogel's or Augustin's method.

For the former process the ore, which has previously been carefully roasted in order to convert the silver into soluble sulphate and at the same time eliminate ferrous sulphate, is charged into a tub provided with a filter bottom and a tap. The tub is on wheels which run on a tramway in order to facilitate removal, and is placed at the upper level of the room so that no subsequent pumping of liquid is necessary. Hot water is supplied to the ore from a tank heated by a small furnace seen on the right of the model, and after percolating through the mass is drawn off and led by launders or channels to the set of wooden tubs seen at successive lower levels. In these the silver is first deposited on metallic copper, and then, in the lowest tanks of all, the copper is precipitated on metallic iron. The resulting liquid containing ferrous sulphate is then allowed to flow away to waste, and the charge of spent ore is thrown down the shoot seen on the left hand of the model, which delivers it into a truck for subsequent treatment.

Augustin's process is conducted in precisely the same way, except that the ore is first roasted with salt and afterwards leached with hot brine.

The silver obtained by these processes is in a granular or "cement" form, and is usually made into cakes under a hydraulic press, and then melted and cast into ingots of 1,000 oz. each.

METALLURGICAL FURNACES AND APPLIANCES.

Some of the metallurgical processes are frequently done at the mine, so that amongst ore-dressing machinery will be found several appliances that could equally well be included in this section; also, with such an extensive subject, all general mechanical appliances have been excluded where other sections for them exist. The most important metallurgical operations are those performed under a high temperature usually obtained by the aid of some description of furnace.

Kilns.—In the preparation of the fuel for the furnace, as well as of the charge, a preliminary heating or reduction is usually performed in a kind of furnace known as an oven or a kiln. Burning the material in heaps, while protecting and regulating the combustion by external coverings, naturally led to the construction of the elementary type of kiln in which the heat from the combustion of fuel mixed with the materials to be calcined is retained and controlled by the masonry walls of an enclosing chamber. Later improvements have chiefly been in the direction of reducing the consumption of fuel and of preventing the loss of valuable by-products that previously were burnt or escaped with the smoke.

Hearths.—A hearth, with some form of bellows, is one of the simplest appliances for the reduction of metals from their ores, and dates back to the earliest civilisation. The hearth consisted merely of a recess in the ground, and the bellows of one or more leather bags formed by the complete skin of an animal. The chief waste in such furnaces arises from the total loss of the heat escaping from the zone of combustion, and from the loss of metal in the slag.

Shaft Furnaces.—These are of as great antiquity as the hearth, and in their simplest forms were small walled enclosures surrounding a fire to which the air was admitted through side apertures, the chimney action and any prevailing wind giving the draught. The mixed fuel and ore were placed in this shaft and gradually heated as the charge descended through the combustion of the fuel in the lower layers until, in the lowest and the hottest zone, reduction or fusing took place. The great advantage of assisting this natural blast by some form of bellows was fully known to the early Eastern races, so that the blast furnace, except by increase in size which caused the product to be cast instead of wrought iron, underwent no important improvement for very many centuries, until 1828, when Mr. J. B. Neilson introduced the use of a heated blast at the Clyde Iron Works; although he heated his blast by a separate fire, the altered conditions under which the combustion in the blast furnace then took place caused a very great saving

in the total amount of fuel used. In 1844 Mr. J. P. Budd used some of the waste gas escaping from the top of the furnace to heat the blast (*see* No. 1219); after that the practice of closing in the tops of the furnaces and utilising the discharged gases for heating the blast and generating steam gradually became general.

In the modern representative of the early blast furnace, the capacity of the chamber may be 20,000 cub. ft., supplied with a blast of 130 tons of air per hour under a pressure of from 4 lbs. to 10 lbs. per sq. in., heated previously to admission to a temperature of 1,000 deg. C., this heating being done by passing the air through stoves (*see* Nos. 1224–5) fired by waste gas from the furnace.

Muffle, Crucible and Retort Furnaces.—In all of the preceding arrangements the fuel and the metal are in direct contact; but for many purposes this is undesirable, partly through the loss and deterioration of the product and partly from the inconvenience in handling it for casting. Melting in ladles and crucibles is therefore adopted, the crucibles being heated in an enclosing fire or furnace. For most purposes, pot or crucible furnaces are urged by a chimney draught, but forced draught is now frequently employed.

Reverberatory Furnaces.—Prevention of contact between the charge and the fuel by the use of crucibles is expensive and can only be done with comparatively small charges, but by burning sufficient fuel in a large grate and directing its flame over a bed holding the charge, this separation can be maintained with even the largest charges. By altering the proportion that the area of the grate bears to that of the bed, almost any required temperature can be obtained, while by the use of damper and air doors the nature of the atmosphere over the charge can be quickly varied as desired. A very important form of reverberatory furnace was that employed in the puddling process for converting cast iron into malleable iron, invented by Henry Cort in 1784, and which for nearly 100 years was the most important means for removing the excess of carbon from cast iron, so as to obtain a tough and reliable material.

The most recent development of the reverberatory furnace resembles the earlier form in the construction of its bed, but is fired by gas prepared in an entirely distinct apparatus known as a gas producer (*see* Nos. 1205–6). The gas mixes with currents of hot air and burns in passing over the bed, while the flame, after leaving the bed, gives up its heat to loosely stacked masses of firebrick called regenerators, which afterwards restore this heat to the gas and air yet to be burnt over the bed, so that an excessively high temperature can be obtained. The practical introduction of gas-fired regenerative reverberatory furnaces was due to Messrs. C. W. and F. Siemens in 1861–7 (*see* No. 1263).

Bessemer Process.—This valuable method of directly converting cast iron into ingot iron or mild steel was introduced by Sir Henry Bessemer in 1856. It consists in blowing air through a bath of molten cast iron, the air of the blast uniting with the constituent impurities from the iron and converting it into steel. The combustion of the impurities increases the temperature of the charge to so marked and valuable a degree that the converter may be considered a form of furnace. Being at the time the only means by which steel could be produced at a price that rendered its use possible for general engineering work, the process rapidly extended and developed until it ultimately became possible to produce steel rails at a lower price than those of wrought iron, while those of steel were admitted to possess from 2 to 15 times the life of wrought iron rails.

Electric Furnaces.—The practical development of a furnace in which electrical energy is transformed into heat was begun by Siemens and Moissan, and only dates from about 1880. The advantages are that a higher temperature can be reached by its means than is possible by the combustion of ordinary fuel, and this is practicable with the refractory materials known owing to the fact that the temperature of the charge exceeds that of the furnace as opposed to the reverse conditions in ordinary furnaces. Electric furnaces are of simple construction and may be divided into resistance and arc heating. In the first the material to be heated may be in the circuit and act as the resistance or it may surround an electrically heated resistance; in the second case the substance forms the poles of an electric arc or is heated by the arc. Generally, an alternating current is used.

Hammering, Rolling, &c.—For the conversion of ductile materials into bars or plates, the most important appliance is the rolling mill. The introduction of grooved rolls for preparing bars and rods is also due to Cort; from the great rapidity of their action it is doubtful if they will ever be superseded. For some materials the greater amount of work done upon them under the tilt or steam-hammer (*see* Nos. 1273 and 1571) is worth the extra cost, but for ordinary rods and bars such treatment would be impracticable. The use of the draw-plate is probably limited to the production of the very small sections known as wire. On the other hand, the method of preparing rods by squirting the material through a die while under a high pressure and temperature is limited to such metals as possess the necessary plasticity at practicable temperatures.

1198. Metallurgical diagrams. Published by Messrs. Chapman & Hall. Received 1890. M. 1430.

This set of 22 diagrams prepared by Prof. W. H. Greenwood in 1886 show to a large scale sectional views of the more important metallurgical furnaces. With one or two exceptions, models of them will be found in the Collection, fully described below.

KILNS.

1199. Model of calcining kiln with condensing chambers. (Scale 1 : 12.) Made by Herr J. Schröder, 1868. M. 1047.

In this form of kiln the larger pieces of the ore to be calcined (iron and copper pyrites or other metallic sulphides and arsenites) are built up upon the floor, leaving a few horizontal air chambers, filled with brushwood, each leading to an aperture in the base. When the kiln is full the top is covered with layers of fine ore often mixed with clay. The mass is then ignited by the brushwood and the fumes pass out through rows of apertures in the back wall into a chamber with baffle wells, where much of the arsenious oxide and sulphide condense, the remaining gases escaping at the chimney. The charges of ore are intentionally burnt very slowly; when finished they are dug out of the kiln, which is then recharged.

1200. Models of coke-ovens. (Scale 1 : 12.) Made by Herr J. Schröder, 1868. M. 1046 & 1048.

The first model shows a circular-domed chamber of brickwork with an octagonal exterior, provided with a side door and a central flue. Coal is thrown into this previously heated vault until it forms on the floor a layer 2 to 3 ft. thick. The volatile products at once distil off and burn beneath the roof, the heat radiated downwards completing the coking in from 48 to 60 hours; the coke is then raked out and quenched with water. Towards the finish the amount of air admitted to burn the gases, which is never large, is still further reduced so as to avoid combustion of the coke.

In the second model the exterior of the oven is of the more usual hemispherical form, and is bound with iron. The oven is built over a chamber and has perforations in its floor through which some of the volatile matter may be withdrawn for the recovery of the coal tar and other products; its sides are provided with perforations for the supply of air, which, however, can be completely shut off.

1201. Model of South Wales coke-ovens. (Scale 1 : 24.) Presented by Messrs. Vivian & Sons, 1856. M. 2704.

The ovens are a series of low vaults placed back to back; each row is provided with a set of rails and each oven with a charging aperture in its roof. The fronts are temporarily closed with brickwork and only enough air is admitted to burn the volatile products; these supply the necessary heat, and the products of their combustion escape by a partitioned chimney that is provided to each pair of ovens. When the coke is finished, it is withdrawn in one mass by the aid of an iron drag that is placed in a groove in the floor before charging; this drag is hauled out by means of a chain operated by a steam capstan. When brought on to the cooling floor the coke is quenched by water from a hose; the coking usually occupies from 36 to 48 hours.

1202. Sectional model of Hoffmann's continuous kiln. (Scale 1 : 24.) Lent by Herr Hermann Wedekind, 1876. M. 1426.

This kiln is chiefly used for burning bricks and tiles or calcining lime and cement. It is the joint invention of Herrn Fried. Hoffman of Berlin and A. Licht of Danzig, patented in 1859, and acts as though a number of kilns were arranged in a ring, and each kiln filled, heated, cooled and emptied in succession; continuous and regular working is thus obtained, while by a regenerative action, the fuel consumption is reduced to a third or a fourth of that usually required.

This kiln consists of an annular tunnel arranged with a chimney shaft at its centre. The tunnel is provided with flues radiating to the chimney, and each flue has a mushroom valve or damper, so that the spent gases can

be drawn off at any desired point; in working, all except one or two dampers will be closed. The tunnel is also provided with doors to the outer air, and with the means of affixing a radial partition across the tunnel space near each door. The number of doors and flues is identical, and in working only one door at a time is open. The partition is always placed immediately between the open door and the open flue so that any air entering by the door must pass completely round the tunnel before it reaches the chimney. The zone of combustion is maintained midway between these two points, and fuel or air can be let in through apertures in the roof. The most recent charge of bricks is put into the section of the kiln by the open door, the partition moved and the valves altered so that the hot gases from the zone of combustion pass over and warm this charge on their way to the chimney. In a similar manner the cold air entering by the open door passes over the finished burnt bricks before reaching the combustion zone, which is thus fed by hot air while the burnt bricks are at the same time being cooled before being withdrawn to make room for the fresh charge.

1203. Model of coke oven and by-product plant. (Scale 1 : 12.) Lent by Messrs. Newton, Chambers & Co., 1899. M. 3077.

This oven is of the "beehive" type, but adapted for the recovery of by-products by modifications patented by Messrs. A. M. Chambers and T. Smith in 1884–9.

The air for combustion is heated by passing it through a circular flue or pipe round the oven and discharging it in an upward direction over the fuel, which is ignited by contact with the hot ovens on either side; by making channels through the fuel, "smudge" or fine coal can be converted.

The floor of the oven is inclined and is made of slotted tiles; it is supported on dwarf walls rising from a floor of still greater slope so that the liquid products collected below drain into a well. The gaseous products pass through a tubular condenser, scrubbers, air condensers, &c., from which the uncondensed gas is led off for use in raising steam. The condensed liquor is treated with lime and steam, to drive off ammonia, which is absorbed by sulphuric acid and converted into ammonium sulphate.

The condensed oil is distilled, washed, and otherwise treated, so as to give oils for illuminating and lubricating purposes, wax and pitch, besides a red brown oxy-hydrocarbon of specific gravity 1·04 from which is derived the disinfectant called "Izal."

1204. Sectioned model of Simon-Carvé's coke-oven. (Scale 1 : 10.) Made by H. Simon, Esq., 1888. M. 1427.

Ovens of this class, of which this is a leading example, have means whereby all the gases produced are drawn off from the coking chamber and deprived of their valuable constituents; they are then returned to the oven and burnt in flues in order to supply the heat necessary for coking. Owing to no air being admitted to the coking chamber, loss by the combustion of the coke is avoided. The model represents one of a range of ovens which may be 30 or 40 in number.

The coking chamber is charged, from two apertures in the roof, with coal brought over the range in railway trucks. The oven, heated from the previous charge, at once causes the gases to be freely evolved, and they are conducted by the pipe A to a gasworks plant to be deprived of their tar and ammonia. They are then brought back along the pipe B, and burnt in a small chamber immediately beneath the oven, giving a flame that passes right along a flue beneath the coking space, thence by horizontal flues in one of the side walls, and then to one or other of two chimney flues (at the extreme end of the model), which traverse the entire length of the range. The flame from the space beneath the next oven in the series passes to the second chimney and so on, alternate fires being connected to one flue. The air necessary for the combustion of the gas first traverses the outer tunnel

of the series of five, then the central one, and finally the inner one, from which each of the gas flames are supplied by a cross flue running beneath the whole length of the combustion chamber. The air is thus well heated, and at the same time prevents the foundation and the brickwork becoming overheated.

The ovens are charged alternately at equal intervals; when the charge is completely coked, it is pushed out at the slightly larger end in one mass by an iron ram from the other end, the ram being worked by a small locomotive steam winch. A set of rails is laid down parallel to the range, to enable the winch to operate upon all the ovens in succession, whilst each coking chamber is provided with iron doors at its ends for the same purpose. The space over the tunnels forms a cooling floor on which the hot coke can be quenched in the usual way.

1205. Sectional model of Siemens's gas-producer. (Scale 1 : 12.) Presented by Sir C. W. Siemens, F.R.S., 1863. Plate III., No. 6. M. 2699.

One of the essential principles of the furnace patented by Messrs. C. W. and F. Siemens in 1861 (*see* Nos. 1263–4) is that the fuel shall be decomposed in a separate "generator," so as to avoid the introduction of solid fuel into the furnace.

The model represents two cells of a single range of such generators or producers. Small coal is fed into the generating chamber through covered apertures, and rests in a thick layer upon a brick slope and a step grate. The lower part of the grate is formed as a water trough, the steam from which checks the combustion on the grate and forms the so-called "water gas" (carbonic oxide and hydrogen), which enriches the simple "producer gas" (carbonic oxide and nitrogen). The gas as it is generated is collected from the producers by means of the tunnel, seen in the left-hand side of the model, from which it rises and passes along a horizontal cooling pipe and then down to the furnace, the difference in the weight of the hot and the cooled columns giving the required draught; gas producers of the present day are, however, almost invariably provided with a closed ash-pit worked by a slightly forced draught. Apertures, covered with iron spheres, are provided in the roof of the producer, through which the interior may be inspected and an iron bar introduced to break down the coal from time to time, and maintain the dense uniform condition necessary for good working.

1206. Sectional model of Wilson gas-producer. (Scale 1 : 12.) Made from drawings prepared in the Museum, 1905. M. 3420.

This producer was patented in 1876 by Messrs. E. Brook and A. Wilson, and was a distinct advance on existing types, embodying as it did a retort portion, a solid hearth without firebars, and forced draught. At first the producer was built rectangular in plan, but about 1880 the octagonal form was adopted and the brickwork enclosed in a cylindrical shell of wrought iron to which doors, &c., could be attached, a construction now universal. The producer is placed in a convenient situation for bringing coal to the level of the staging.

The "slack" coal is fed through a hopper into the retort which is in the form of a conical curtain wall, the intention being that the heavier hydrocarbons there distilled should pass downward through hotter fuel and suffer decomposition before reaching the exit holes leading to an annular chamber surrounding the retort, and thus avoid the subsequent deposition of tar in the gas main. The rate of combustion is regulated by the air induced by the action of an injector consisting of a steam jet opposite the narrow throat of a tapered vertical pipe. The mixture, in the proportion by weight of about 1 of steam to 20 of air, is delivered at a pressure of

1 to 3 in. of water to a rectangular tuyere which has three openings at each side in the centre of the hearth,—the most economical point. Incomplete combustion takes place with the formation of carbon monoxide; part of the heat evolved, however, is absorbed by the decomposition of the steam. This takes place near the tuyeres, keeping that region cool and rendering the clinker brittle. The latter is raked out at intervals of about 24 hours through two doors, one on each side of the tuyere, the fuel being meanwhile supported by a number of iron bars driven in at a shallow door and resting on the tuyere. This operation requires about half an hour, the producer being shut down meanwhile by the damper. The gas produced passes off at a temperature of about 430 deg. C. by a pipe leading from the annular chamber either through a down-comer to an underground flue, or through brick-lined tubes above ground.

The average composition of the gas by volume is 24 per cent. CO; 12·5 per cent. H; 3·5 per cent. other combustible gases; 5 per cent. CO_2 and 55 per cent. N. About 140,000 cub. ft. are produced for each ton of fuel.

The size shown would gasify upwards of 8 cwt. of coal per hour or at the rate of about 25 lbs. of fuel. per sq. ft. of hearth area—*i.e.*, double the rate of Siemens's sloping grate producer.

1207. Model of Dowson gas plant. (Scale 1 : 8.) Lent by the Dowson Economic Gas & Power Co., 1895. M. 2733.

This represents a complete plant for producing heating gas by the method introduced by Mr. J. E Dowson in 1883. The gas is prepared by passing a current of steam and atmospheric air upwards through a mass of red hot coke or coal, which results in the delivery above the producer of a mixed gas, containing from 15 to 25 per cent. of hydrogen and 20 to 25 per cent. of carbonic oxide, the remainder consisting of inert gases. This producer gas, although not suited for lighting, can be used for general heating purposes, and can be also employed for driving gas engines, a method of obtaining power that has been found very economical, a horse power being obtained with a consumption of 1 to 1·5 lbs. of anthracite coal per hour.

The plant shown consists of a small vertical boiler supplying steam to a form of injector, which induces an air current that, together with the steam, enters the ash-pit of a vertical fire-brick lined chamber, known as the generator. The generator is provided with a closed charging hopper at the top for introducing the fuel, and the grate is maintained covered with a thick fire, in passing through which the steam is decomposed while the combustion of the fuel is supported by the air also carried in. The gas produced is cooled and purified by being led from the generator to a hydraulic box, then through a coke scrubber and a sawdust scrubber to the gas-holder, from which it is withdrawn as required. The gas-holder is only introduced to correct any irregularity in the working of the plant, and is consequently small; it has been arranged so that the position of the holder shall control the admission of steam to the injector, thus automatically adjusting the production of gas to the consumption.

The calorific value of this gas is about 25 per cent. of that of coal gas, but it is stated that the cost, including fuel, wages, &c. is only 9 to 12 pence for the equivalent in heating power of 1,000 cubic ft. of ordinary town gas. The model represents a plant capable of supplying gas to an engine indicating 50 H.P.

1208. Model of gas producer plant. (Scale 1 : 48.) Made in the Museum from information supplied by The Power-Gas Corporation, Ltd., 1907. Plate III., No. 2. M. 3426.

This shows a plant for making producer gas regeneratively, and recovering the ammonia, the product being suitable for power purposes in large gas engines.

An inferior grade of bituminous coal, such as "slack" or "dross," is discharged direct from railway wagons into a well, whence it is raised by an elevator and distributed by conveyors to each row of three producers. The fuel is admitted by sliding necks and measuring hoppers to the producers which are of the form patented in 1893 by Dr. Ludwig Mond, F.R.S.; each consists of a double wrought iron shell lined with firebrick, the lower part of the inner shell being formed as a conical grate and that of the outer shell made to dip into a water seal. Heated air and steam are blown through the annular space between the shells and through the grate, the reaction with the fuel resulting in the formation of hydrogen, carbon monoxide, marsh gas, and a trace of ammonia, diluted with nitrogen and carbon dioxide. The heat evolved is, to a great extent, regenerated, and it is in this direction that the Mond system is an advance on previous practice. The ashes sink into the water seal and are raked out at intervals without stopping the production of gas. The temperature of working is kept low, as this is favourable to the production of ammonia and unfavourable to the clinkering of the ash; this is done by using a weight of steam 2·5 times the weight of fuel gasified, but a weight equal to that of the fuel is subsequently recovered. Where the fuel consumption is less than 30 tons per 24 hours, the expense of ammonia recovery plant is not usually incurred. In that case the weight of steam used is limited to that of the fuel gasified.

After leaving the producer the gas passes through a regenerator which is simply a series of jacketed tubes, the blast of air and steam being in the jacket and the gas inside. It is then delivered to a mechanical washer in the space between the producers. This is a rectangular wrought-iron chamber where the gas is met by fine spray thrown up by rapidly revolving dashers driven by belting. The heat of the gas is rendered latent by the formation of steam at a temperature of about 90 deg. C., and the dust and soot, &c., washed out are removed by an arrangement of lutes in the sides of the washers. The gas then ascends the acid tower through chequer brickwork over which falls a shower of sulphuric acid in weak solution, the ammonia combining with it to form ammonium sulphate.

The acid solution is kept circulating till it contains 36–38 per cent. of this salt, when a small stream of the liquor is allowed to run off and is made up for by fresh supplies of sulphuric acid.

The gas is next passed to the bottom of the gas-cooling tower, where it is met by cold water trickling over wood packing. The water vapour with which it is charged condenses, and this, together with the water that has been used, is pumped to the top of the air-heating tower, where it serves to warm and saturate the air blast on the way to the producers and is thereby cooled sufficiently for use over again in the gas-cooling tower.

A separate building is set apart for the concentration of the ammonium sulphate liquor. After being neutralized it enters conical evaporators heated by steam at 35 lbs. pressure in coils of lead piping; the crystals after being drained are dried by a hydro-extractor. The quantity realized is about 90 lbs. per ton of fuel gasified. There is a power-house to accommodate the Roots blower, water and acid circulating pumps, and an engine for driving the washers.

The plant represented is for gasifying 120 tons of fuel per 24 hours; one ton will produce about 150,000 cub. ft. of gas at ordinary temperature and pressure. The percentage composition by volume averages: hydrogen, 27·5; carbon monoxide, 11; marsh gas, 2; the remaining 59·5 per cent. being diluent. About 60 cub. ft. are required to develop one indicated H.P. in a large gas engine.

HEARTHS.

1209. Sectioned model of ore-hearth (Scale 1 : 12.) Presented by John Taylor Esq. F.R.S. 1843. M. 2709.
Model of Scotch slag hearth. (Scale 1 : 8.) M. 2712.

The ore hearth is a furnace made of cast-iron blocks set in brickwork and used for the reduction of very pure lead ores. The roasted ore is charged into the hearth with coke or charcoal as fuel, and exposed to the action of a blast of warmed air supplied from the back of the hearth. Much of the lead is at once reduced at a low temperature and runs off by a gutter into a receptacle; the remainder of the charge is raked out and exposed to the air on the "work-stone" seen in front of the hearth, the pasty portions being then returned to the furnace interior, whilst the vitrified "grey slag" is charged into a "slag hearth," and there reduced by true blast furnace treatment.

The slag hearth is provided at its base with a "syphon tap" which in practice is filled with ashes; through these the lead, as it collects, rises and flows to the middle division of an iron pan seen in the base of the structure, from which it is ladled from time to time.

1210. Model of iron refinery hearth. (Scale 1 : 6.) Made by Herr J. Schröder, 1868. M. 1042.

This obsolete form of furnace resembling a smith's hearth consisted of two flat fires each urged by a current of air from a blast pipe inclined downwards. The pig iron to be refined was placed on a layer of hot coke or charcoal and the blast urged until it was melted; the large excess of air employed caused a great deal of oxidation, so that the silicon in the iron was removed and the charge rendered suitable for the puddling furnace which afterwards removed the carbon. When the operation had proceeded far enough the refined metal (a kind of "white" iron) was run out and cast in a recess provided in the floor between the two hearths. The sides of the hearth were generally formed of water-cooled iron troughs lined with a layer of the slag.

1211. Sectioned model of finery hearth, Walloon process. (Scale 1 : 20.) M. 2701.

This type of furnace was used considerably for the conversion of cast into wrought iron, by fusing it in an oxidizing flame and then working in a bath of iron oxide slag contained on the hearth.

The hearth, built up with iron plates, has the floor plate water-cooled and is lined with charcoal. The fuel, usually charcoal, is placed in the hearth and the combustion forced by a cold blast from a tuyere inclining downwards. The cast iron is slowly melted off the end of a long pig or slab overhanging the hearth and fed in from the left-hand side. The partially purified iron is subsequently almost completely decarbonised by being worked in the molten bath of iron oxide, and when in the pasty condition is collected into a ball and forged into bars. Through a hole in the front of the hearth any excess of slag is discharged. The hearth is surmounted by a brickwork chimney across which are baffle plates.

1212. Model of lead fume condenser. (Scale 1 : 12.) Contributed by the Commissioners for the Exhibition of 1851. M. 1740.

This plant was in use at the Wanlockhead lead mines of the Duke of Buccleuch for arresting the solid particles contained in the fume or smoke from the "hearths."

It consists of a rectangular building of masonry about 30 ft. high divided by a partition into two chambers, in one of which are baffle plates past which the fume from eight furnaces travels four times while meeting a shower of

water from a reservoir at the top of the building. The fume then passes through a grating 2 ft. wide filled with coke washed by water, and finally down the other chamber, where it is washed by showers of water discharged intermittently by a gridiron slide valve reciprocated by a water-wheel which also pumps the water back to the tank on top. The fume so arrested is collected in slime pits, and contains about 33 per cent. of lead with 4·5 oz. of silver to the ton.

SHAFT FURNACES.

1213. Sectioned models of small Saxony blast furnaces. (Scale 1 : 16.) M. 2703 & 2706.

One of these is a single furnace and the other a double one; such furnaces were formerly employed at Freiberg for the reduction of impure argentiferous lead ores. The shafts are rectangular and the hearths are moulded from a mixture of coke dust and clay in the form of a basin in which the reduced metal collects, and is tapped off at intervals of 6 hours into a depression at a lower level; a dam is provided over which the slag flows continuously. The blast was cold and supplied at a very slight pressure. The product was cupelled in No. 1253.

1214. Sectioned models of blast furnaces. (Scales 1 : 24 & 1 : 32.) Made by Herr J. Schröder, 1868. M. 1044–5.

The first is a furnace with open breast, forehearth, and tunnel head, closely resembling No. 1216.

The second represents an old English charcoal iron furnace with closed breast and only two tuyeres; it has an independent firebrick lining separated by a layer of sand from the massive external masonry.

1215. Sectioned model of charcoal blast furnace. (Scale 1 : 32.) M. 2702.

This represents a German furnace using charcoal as fuel. The upper part is a truncated cone of masonry held together by iron bands; in other respects it resembles No. 1216.

1216. Model of South Wales blast furnace. (Scale 1 : 12.) M. 1753.

This shows a blast furnace at Penydarren Iron Works, and represents a large example of the construction adopted in South Wales prior to 1850.

The furnace was a truncated square pyramid, constructed of massive masonry with an independent lining of firebrick blocks separated from it by a layer of sand. Four arched openings were left in the base, one for the fore-hearth and tapping-hole and three for tuyeres; these were connected by a tunnel conveying the blast main. The ore and fuel were fed in at the open top, through four openings in the tunnel-head. The blowing engine (*see* Part I. of Catalogue) supplied blast at a pressure of 2 or 3 lbs. per sq. in., to two cold blast tuyeres through leather "goose-necks," (missing), and to one hot blast tuyere through a ball-and-socket jointed cast iron goose-neck. The small pipe stove employed, by which the blast for the latter was heated to a temperature of 370 deg. C., was arranged at one side; it consisted of nine semicircular cast-iron pipes placed parallel in a chamber heated by a coal-fire.

1217. Sectional model of anthracite blast furnace. (Scale 1 : 24.) M. 2700.

This represents a blast furnace used at Gwendreath, South Wales, about 1850.

The inside shape is roughly that of two truncated cones with their bases together and a hearth of rectangular section below. In three sides of the

hearth are inserted the seven tuyères, 1·5 in. to 2·75 in. diam., and on the fourth is the cinder-notch. The furnace was 30 ft. high, 4 ft. sq. at the hearth, 12 ft. diam. at the boshes, and 8 ft. diam. at the throat.

The charge to produce 1 ton of pig was: 35 cwt. of anthracite, 45 cwt. of calcined ironstone, and 16 cwt. of limestone. 3,000 cub. ft. of blast at a pressure of 2·25 lbs. and temperature of 320 deg. C. were supplied per minute; the make was 105 tons per week.

1218. Model of Welsh blast furnace. (Scale 1 : 24.) Presented by Frederick Levick, Esq., 1851. M. 2696.

The furnace represented was erected at Blaina Iron Works, South Wales, about 1850.

It has a cylindrical shaft on a square base, with three tuyères and the usual cinder notch and tap hole. A pair of cast-iron bearers, crossing one another just below the top, carry a cast-iron cone to distribute the charged material. A wrought-iron tube is placed concentrically with the cone, but not quite touching it, and outside slides another tube suspended by flat link chains from an arched lever; the latter, when lowered on to the cone, completely closes the top and the gases pass away through a rectangular tube, controlled by a butterfly valve, to be utilised.

1219. Sectioned model of blast furnace with hot air stove. (Scale 1 : 16.) Presented by J. P. Budd, Esq., 1852. M. 1745.

The economy due to heating the air supplied to a blast furnace was first demonstrated in 1828 by Mr. J. B. Neilson at the Clyde Iron Works, where he used a coal-fired stove to heat the blast. Several attempts were subsequently made to attain the same result by utilising the sensible heat of the waste gases, but the first successful arrangement of this kind was that introduced by Mr. Budd in 1844, and fitted to a row of six anthracite furnaces at the Ystalfera Iron Works, South Wales.

The model represents one of the furnaces so fitted; it was open-topped and similar in construction to that shown in No. 1216, but at about 3 ft. below the top had 3 or 4 nearly horizontal flues, about 12 in. diam., leading to a chamber supported on an arch and incorporated in the masonry. This chamber contained a series of upright ∩ pipes, connected to cross pipes from the upcast cold blast main on one side and the downcast hot blast main to the tuyères on the other. A chimney, about 25 ft. high, was added to draw off the required amount of gas from the upper part of the furnace, through the chamber; there was a controlling damper on the top of this chimney, and a small door in the stove front for the admission of air when the stove was being cooled for repairs.

The waste gases were at a temperature of 982 deg. C., and left the stove at 455 deg. C., heating the blast to 314 deg. C. above which at the time it was considered inadvisable to go. Combustion of the gases was therefore unnecessary.

1220. Sectional model of blast furnace plant. (Scale 1 : 20.) Received 1856. M. 2784.

This shows the water-seal method of closing the top of a blast furnace, in order to collect the waste gases, invented by Messrs. A. C. Laurens and L. P. Thomas about 1854–55.

The throat of the furnace is closed by a tube and a cover (shown detached) on which is a cup that can slide on three pillars for charging; when down the edge dips into an annular water seal. The gases are taken off at opposite sides by two tubes leading to the gas mains which have water-sealed troughs of water suspended below to catch the dust. Part of the gases are burnt in the heating stove, which consists of a combustion chamber containing several upright pipes with internal radiator cores; the blast is heated by passing through the annular space between them. All the joints

are accessible from outside. Another part of the waste gases is used for raising steam—an application first made in 1835 by Messrs. Laurens & Thomas at the works of Echalonges. The boilers are of the externally fired elephant type, with a cylindrical shell above connected to a heater of less diameter below. The flame passes from the main shell to the heaters, the course of the feed-water being in the reverse direction.

1221. Model of the Ayresome Iron Works. (Scale 1 : 96.) Lent by Messrs. Gjers, Mills & Co., 1891.
M. 2369 and 2372.

This represents the general arrangement of these iron works, situated on the River Tees at Middlesbrough, built in 1870, and covering an area of 32 acres.

The raw materials, in the shape of ironstone, coke, and limestone, are brought in wagons to an inclined road, down which they descend by gravity to a pneumatic hoist, which lifts them a height of 35 ft. to the gantry passing over the depôt and calcining kilns. The ironstone is tipped into these kilns, of which there is a set of four to each pair of furnaces; the coke into two boxes, situated between the sets of kilns; small coal for the kilns into a depôt close to the hoist, and the limestone into two bunkers, one at each end of the sets of kilns. The kilns, patented in 1863 by Mr. J. Gjers, each consists of a shell lined with firebrick resting on a cast-iron ring supported on columns so as to leave an opening at the bottom of the kiln through which the calcined stone is withdrawn. The kilns are 33 ft. high by 24 ft. diam., and are each capable of calcining 1,000 tons of ironstone per week. After being emptied the wagons run by gravity to the further end of the gantry, where they are lowered to the level by a hoist and despatched to sidings. The ironstone, coke, and limestone taken from the depôts are filled into iron barrows, which, after being weighed, are elevated to the furnace tops by pneumatic hoists, which are made of cast-iron flanged cylinders 36 in. diam.

The furnaces, which are built of brickwork hooped with iron, are 85 ft. high and 25 ft. diam. at the boshes. They are closed with the cup and cone arrangement, the gases being carried through tubes into a culvert below and thence distributed to the stoves and boilers. They are each blown by five tuyères and are equal to the production of about 2,500 tons of pig iron per week.

For each furnace there is one hot blast stove, consisting of 14 double-legged pipes of flat section. The cold blast from the main enters each stove by means of a breeches pipe connected outside, and the hot blast passes out by a similar pipe at the opposite end of the stove and is delivered into a horse-shoe main which passes round the furnaces. Each stove has an ordinary firegrate to enable firing to be done in case of stoppages, but this grate is closed up when the stove is at work.

Twelve egg-ended boilers, each 4·5 in. diam. by 60 ft. long, provide steam for three vertical direct-acting blowing engines, one of which is, however, always held in reserve. They work at 50 lbs. steam pressure and supply the blast at a pressure of from 4·5 to 5 lbs. A series of fountains are used to cool the water from the tuyère coils.

Specimens of the various numbers of foundry, hæmatite, ferro-silicon, and silico-spiegel-iron made at these works are shown.

1222. Sectional model of blast furnace. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., from information furnished by E. P. Martin, Esq., 1900. Plate III., No. 3. M. 3128.

This represents one of the four furnaces at the Cardiff steel works of the Dowlais Iron, Steel, & Coal Co., South Wales.

The hot blast is admitted through eight tuyères, while above them are four "monkey" tuyères by which cold blast can be introduced should the charge show any signs of "scaffolding." The tuyères are cooled by water

circulating through wrought-iron pipes cast in their walls, and the boshes of the furnace are cooled by 40 cast-iron blocks through which water is circulated in the same manner; the cooling water for both is supplied from an annular channel, from which it passes to distributing boxes and regulating cocks.

The furnace top is closed by the cup and cone arrangement; the cone or bell is supported by rods from two levers mounted in bearings on supporting girders and connected by a linkage that ensures vertical motion. It is counterbalanced and is moved by hand gearing controlled by a brake. When the top of the furnace is closed the gases pass through the "downcomers" to an underground flue, from which they are led to the hot blast stoves and boilers, where they are burnt. The charge of coke and ore, with limestone to act as a flux, is tipped into the cup out of small barrows which are raised to the gallery at the furnace top by a hydraulic hoist. When the bell is lowered and the charge enters the furnace, the escaping gas is ignited by a fire kept constantly burning at the top of the furnace so that the poisonous carbon monoxide is converted into the less dangerous carbon dioxide; the charging mechanism is provided with an iron shelter for the protection of the workman.

The slag, which floats above the molten metal in the hearth, is run off at intervals into ladles mounted on railway trucks which, after being hauled to the slag heap, discharge their loads by side tipping. The molten metal is tapped at intervals into a sand channel which leads it to the pig beds, where it is cast into the form of large combs which, when cooled, are carried to a hydraulic machine by which the pigs and sows are broken into short lengths and discharged into railway trucks. The blast furnace represented is 75 ft. high from the hearth, and 85 ft. from the works rail level; the diameter at the hearth is 10 ft. and at the boshes 20 ft.; the output of the furnace is about 1,300 tons of pig iron per week.

The blast is heated by Cowper stoves (*see* No. 1224) each 68 ft. high by 24 ft. diam.; three stoves are provided for each furnace so that, in addition to the pair working alternately, there is a spare one for use when repairs become necessary.

On the ground level, instruments are provided for recording on paper strips moved by clockwork the temperature of the blast, the times of charging, &c.

1223. Model of blast furnace charging apparatus (working). (Scale 1 : 48.) Presented by J. L. Stevenson, Esq., 1904.
M. 3372.

The older blast furnaces were erected on hillsides, so that the charge could be wheeled direct to the top. As dimensions increased improved methods of raising the materials became necessary; the inclined plane was used to some extent, but the vertical hoist is most general in this country and abroad, except where the inclined hoist is used in the latest plants.

The arrangement of inclined hoist shown was patented in 1897 by Mr. Stevenson. Under this system each furnace requires a separate hoist, but the outlay is justified with an output of over 150 tons of pig iron a day, as this necessitates the handling of about 500 tons of raw material. Instead of, as usual, filling the charge into barrows and hoisting them to the bell at the top, it is tipped into skips at the ground level. The skips run on rails on the lower flanges of the inclined lattice girders, and one ascends while the other descends, being drawn up and lowered by ropes from an engine or electric motor below. When the top is reached a cross-bar on the skip engages in elliptical guides on the under flange of the girders and automatically tips its contents into a hopper. When it is full the bell of the hopper is lowered pneumatically, permitting the charge to fall into the usual cup and cone arrangement below. When sufficient material has accumulated there, that cone is lowered and the charge descends into the furnace. These operations can be controlled from the ground level by the lift engineman,

requiring no labour at the top. The arrangement gives a good distribution of material in the furnace and prevents escape of gas when lowering the bell.

1224. Sectional models of hot blast stoves. (Scale 1 : 24.)
Received 1897. M. 2973–4.

These two models show the construction of the apparatus patented by Mr. E. A. Cowper in 1857, for utilising the waste gases from blast furnaces to heat the blast; they are a type of "regenerator," and by their use the consumption of fuel per ton of pig iron reduced is greatly diminished. The stoves are arranged in pairs, one stove absorbing heat from the waste gases while the other is giving off its previously absorbed heat to the blast, the process being reversed at intervals as the stored heat is abstracted.

Each stove consists of a vertical shell of wrought iron, to give the strength necessary to resist the pressure of the blast, lined with firebrick, and containing a large vertical passage or "flame flue" built in firebrick. The waste gases are brought in below the base of this chamber and pass up into it through three ports, there mixing with the requisite amount of air for combustion from an air inlet valve. The mass of flame then passes to the top of the stove and returns downward through a large number of small passages built in firebrick to which the heat is transmitted, the cooled products passing by an underground flue to a chimney. While this is going on the blast for the furnace is being sent through the other stove in the reverse direction, so that the cold blast first meets the coolest part of the stove and passes on to the hottest. The extreme temperatures of the firebrick do not greatly differ during the cycle, the regenerative action depending rather on the extent to which the high temperature extends towards the cooler part of the stove, or upon the change in the average temperature of the total amount of firebrick. The stoves are cleared from dust by firing a small gun into an aperture near the base, but it has since been found that by suddenly releasing the pressure in a stove the passages are very effectually cleaned.

In one of the models the regenerator brickwork is formed of rectangular bricks on edge, bonded in a way which leaves passages that, while facilitating the absorption of heat, have ledges upon which dust deposits. The other model shows the modification that was subsequently introduced to avoid this difficulty; special firebrick blocks, known as "honeycomb filling," are used, which, when fitted together, leave a large number of hexagonal channels that, while easy to clean, present a great amount of heating surface. Two of the actual bricks are shown below the case, one being from the top course in which the partitions come to an edge. Two diagrams (scale 1 : 8) on the wall show a sectional elevation and plan respectively of this later form.

1225. Sectional model of hot blast stove. (Scale 1 : 12.)
Presented by W. Whitwell, Esq., 1872. M. 1751.

The feature of this form of firebrick stove, patented by Mr. Whitwell in 1865, is that the heated gases are passed through long channels with comparatively smooth walls of firebrick, instead of through the shorter but more tortuous passages of the Cowper stove (*see* No. 1224).

The waste gas from the blast furnace, used to heat the stove, is burnt in the large vertical combustion chamber on the right-hand side, sufficient air for the purpose being admitted by a special valve near the base of the stove. The heated products of combustion then pass repeatedly down and up the stove between the partitions, heating them and finally passing to the chimney valve on the extreme left. As in the case of the Cowper form, two stoves at least are necessary, one being heated whilst the other is heating the blast. Small passages are left in the brickwork for the purpose of inspection and for determining the temperature, while openings in the roof and in the rear of the stove are provided through which dust can be detached from the walls and be removed. The roof of this stove is flat, supported by wrought-iron girders, and is provided with doors for cleaning the vertical passages.

1226. Models of regenerator bricks. (Scale 1 : 4.) Presented by J. L. Stevenson, Esq., 1904. M. 3377.

These represent different forms of bricks for filling the interior of hot blast stoves and for the chambers of regenerative furnaces, patented in 1898 by Mr. Stevenson and Mr. J. Evans.

The brick is of a double cruciform section which leaves square openings when filled in. For hot blast stoves the bricks are laid so as to give uninterrupted square vertical passages, at the same time breaking joint. For regenerative furnaces the bricks are laid so that one layer interrupts the openings in the layer above and below. For a given cubic capacity, the thickness being the same, the square filling has greater heating surface but less volume than Cowper's hexagonal section (*see* No. 1224).

1227. Hot blast tuyères. Received 1885. M. 2778.

These are two specimens of Staffordshire tuyères of the type invented by Condie, the object of the arrangement being to prevent the blast pipe from being burnt away where it discharges its blast into the hearth of the furnace. These tuyères are hollow truncated cones, the annular space being supplied with cooling water constantly circulating. One of the tuyères is of gun-metal in half section, and is screwed for ·625-in. diam. pipes: the other is of wrought iron welded up (an unusual construction) and shows the method of attaching the pipes, 1·25 in. diam., for the cooling water.

1228. Model of cupola with fan blower. (Scale 1 : 8.) M. 2711.

This is a small cylindrical shaft furnace for remelting pig and scrap iron for the production of castings. It has an iron shell lined with firebrick and is provided with a charging door, a hood, and a stack. The blast is admitted through two opposite tuyères, but to permit of the accumulation of a large quantity of molten metal when required for a heavy casting, there are three rows of tuyère holes, those not in use being stopped with firebrick plugs. The two tuyère pipes are connected to the blast main by a telescopic length that permits of the ready alteration of the height of the tuyères: The blast is supplied by a belt-driven centrifugal fan.

1229. Sectional model of Stewart's cupola and receiver. (Scale 1 : 8.) Lent by Messrs. Thwaites Bros., 1890. M. 2301.

This cupola, patented in 1883 by Mr. A. Stewart, has three zones of fusion diminishing in depth towards the bottom where the highest temperature is required. The tuyères in the top zone are provided with separate plug valves. The blast is supplied from an annular air-belt, which is divided into two compartments, each being controlled by a stop-valve. If the tuyères in one compartment get blocked with slag, they can be cleared by shutting the stop valve in that half and keeping the other open, when the hot gases will blow through and melt the slag in a few moments; by repeating this operation when required the tuyères can be kept clear without having to perch through with a bar. At the top of the cupola are two damper doors which can be adjusted to deflect the sparks as desired.

The cupola is mounted on pillars carrying a cast-iron drop-bottom with wrought-iron hinged doors, which can be dropped after every blow to let out the ashes, &c,, and keep the brick lining in good working order. To collect the metal as it is melted, a receiver lined with firebricks is provided, the top having an air pipe for conveying the hot fumes back again to the cupola.

On an average of six tests, 1 lb. of coke, inclusive of bed, melted 13·2 lbs. of iron, or 1 cwt. of coke, exclusive of bed, to 19·7 cwt. of iron. The blast should be supplied at a pressure of ·75 lbs. per sq. in. A cupola of the size represented is suitable for melting 5 tons of iron per hour.

1230. Model of water-jacketed blast furnace. (Scale 1 : 10.) Received 1889. Plate III., No. 7. M. 2721.

This represents a type of furnace introduced at Freiberg in 1865 by Bergrat Pilz, and now extensively used in Europe and America for smelting copper and lead ores. Its leading feature is the presence of a water-cooled belt round the hottest zone, which cools the walls of the furnace, and thus diminishes the wear where it would otherwise be most rapid. The heat carried away by the water is a direct loss, but is, however, much more than compensated for by the longer life and reduced cost of maintenance of the furnace thereby attained; by some it is considered, moreover, that the lowered temperature of the hearth prevents the reduction of iron in certain ores in which it occurs as an impurity.

The shaft of the furnace is of brick in an iron shell, and is carried on metal columns so that it is not disturbed when repairs are being effected in the hearth. The hearth is of brick, and upon it rests the water belt, which is built up of eight segmental boxes, each pierced by a tuyère and supplied with circulating water. In the early Pilz furnaces the tuyères were arranged between the segments of the belt. Blast is supplied at a pressure of about ·7 lbs. per sq. in. from an octagonal main; the charge is fed through a closed cylindrical trunk at the top, and the waste gases escape through a side flue.

The molten metal, regulus, and slag collect in the hearth, and at intervals the regulus and slag are tapped into slag pots, while at longer intervals the molten metal is run out through two tap holes at the bottom of the hearth.

MUFFLE, CRUCIBLE AND RETORT FURNACES.

1231. Sectional model of cementation furnace. (Scale 1 : 12.) Presented by Messrs. Naylor, Vickers & Co., 1851. M. 1749.

This forms part of a complete model illustrating the manufacture of steel in Sheffield in 1850 (*see* Nos. 1239 and 1273–4).

The cementation process, for converting wrought iron into steel, consists in maintaining wrought iron for several days at a red heat while embedded in charcoal and protected from the air, whereby the iron gradually absorbs carbon, which combines with it and converts it into steel. The method is a development of the case-hardening processes, and is very old, but Réaumur, in a work published in 1722, appears to have been the first to experimentally examine it; he also describes the furnaces then in use, which were very similar to those employed at the present day at Sheffield and elsewhere.

The wrought iron to be treated, usually in the form of 3 in. by ·75 in. high quality flat bars, is packed in open rectangular chests or "pots," built of sandstone or firebrick, which are built on either side of a long coal-fired grate, the products of combustion being caused to completely surround them by being led through a series of flues along the bottom, sides, and ends of the chests. These flues open into an enclosing arched firebrick chamber, provided with doorways at the ends, and three short chimneys on each side just at the springing of the arch, so as to create a distributed draught. The whole is sheltered under a hollow cone of brickwork about 50 ft. high, which retains much of the heat, and delivers the waste gases at a sufficient elevation, while preventing the formation of a strong draught.

These cementation plants are usually built in groups, as shown, with each chest measuring from 10 to 15 ft. in length by 2·5 to 3 ft. square, and holding 8 to 12 tons of wrought iron. The bars are packed between layers of wood charcoal, and when the chest is full the top is plastered over with clay or "wheel-swarf," a mixture of silica and oxide of iron from the grinderies which, when heated, frits and forms an airtight lid. The entrances of the chamber are walled up and the fire lighted, so that in

two or three days the chests are at a glowing red heat, *i.e.*, a temperature of 1,170 deg. C., which is maintained for five or six days. The fire is then drawn and the furnace allowed to cool during two or three more days, in which time, however, the process is still proceeding and completing itself. At intervals during the process, bars left protruding from the chests are withdrawn from the lowermost side openings, in order to judge, from their fracture, of the extent of the conversion, which is varied according to the purpose for which the steel is to be used. The coal consumed is about equal in weight to that of the steel produced, and the capacity of each furnace is about 6 tons per week. The surfaces of the bars after treatment are covered with blisters of various sizes (*see* No. 1241), so that this material is known as "blister steel." In this form it is very rarely used, but is subsequently forged into some of the various grades of shear steel, or else melted in crucibles.

1232. Sectional model of furnace for malleable iron castings. (Scale 1 : 12.) Made by B. L. F. Potts, Esq. from information furnished by Robert Booth, Esq., 1902. M. 3227.

The method of toughening white or mottled iron castings by roasting them in oxide of iron, so as to remove some of the carbon present, and thereby convert the metal into a material resembling wrought iron, was patented by Samuel Lucas in 1804; the furnace represented is a modern one as now employed for carrying out this extensively adopted process.

The model shows one complete chamber and another chamber in section of a double furnace, arranged in a shallow pit. Each chamber has an arched roof, and a central firebrick platform upon which the boxes containing the castings to be treated are stacked. Along each side of the platform extends a grate, the heated gases from which, after passing upwards and amongst the annealing boxes to the roof, descend through a flue in the front wall into a larger flue beneath the platform, from which they pass to the stack (not shown), thus giving up some of their heat to the brickwork. The back of each chamber has a large arched opening which, after the boxes have been placed in position, is bricked up, a loose brick alone being left to provide for inspection. The furnace walls are supported by vertical "buckstaves," made of old rails tied together above and below by through rods, additional stays being placed at the sides to resist the thrust of the roof arches.

The castings to be treated should be as free as possible from sulphur and phosphorus, and as the rate of conversion diminishes gradually as it proceeds inward, thick sections should be avoided; also the process is more successful with small than with large castings. The castings are packed in iron boxes or "saggers" with oxide of iron in the form of powdered red hæmatite, or of scale from the rolling mills. The temperature of the furnace is gradually raised during 24 hours to a bright cherry red, at which it is maintained for from three to seven days. The boxes are then removed and allowed to cool slowly; the castings are usually finished by "rumbling." The mill scale and the spent oxide from the boxes are frequently treated with a weak solution of sal-ammoniac, to promote the combination with them of oxygen from the atmosphere, so as to serve again.

1233. Malleable iron castings. Lent by Messrs. John Crowley & Co., 1888. M. 1959.

These specimens have been treated by the malleable process (*see* No. 1232) and show various uses to which the resulting material can be put; some have been tested cold to show the ductility that may be obtained. The serrated bars are beater bars for thrashing machines (*see* No. 1528).

1234. Crucible furnace, crucible and salamander. Presented by the Morgan Crucible Co., 1890. M. 2360–1.

This furnace, patented in 1877 by Mr. J. Fletcher, is chiefly used for melting brass and similar alloys. It consists of an inner and outer shell of

cast iron, the former at the bottom having an internally projecting flange which supports the firebrick lining. The outer shell, which is carried on three feet, is provided below with a hinged concave door forming a drop bottom. An air blast, supplied through a pipe with a sluice valve, is introduced at the top of the space between the two shells and, passing downwards, is heated by otherwise waste heat before it enters the furnace at the annular opening left between the flange of the inner and the bottom of the outer casings. The waste gases from the furnace escape through the upper side opening which may, if more convenient, communicate with a stack giving sufficient draught without the use of a fan. At the conclusion of the work the fuel and clinker are quickly removed by knocking out the cotter that retains the drop bottom.

The crucible, which is machine-moulded, is formed of a mixture of fireclay and plumbago by which more meltings can be resisted than is possible with those of fireclay only.

The salamander is a perforated support of the same material, by means of which the crucible is maintained in the hottest part of the furnace, and also protected from the injurious action of the entering blast. A few inches of coke are, however, necessary between the two appliances.

A vertical sectional drawing of the furnace (scale 1 : 2) shows them in position.

1235. Crucible furnace. Presented by the Morgan Crucible Co., 1902. M. 3221.

This coke-fired furnace, for melting iron, brass, and the precious metals in crucibles, was patented in 1880 by Mr. Charles Carr, and improved in 1894 by Mr. J. J. W. Carr. The furnace casing is of plate iron with angle irons at the corners extending downward to form feet. The firebrick lining, which is in one piece, rests on a cast-iron plate a few inches above the firebars, thus leaving space for the admission of air over as well as between them; the space between the casing and the lining is filled with some non-conducting material. The side flue, by which the furnace is connected with the chimney to give the necessary draught, is similarly constructed in one block, and is carried by cast-iron plates dovetailed together and forming a bracket. The crucible and stand used are shown on an adjacent pedestal.

1236. Miller's apparatus for purifying gold, in section. M. 2715.

This process, introduced by Mr. F. B. Miller and used in the Sydney Mint, consists in blowing chlorine gas through the molten alloy; the chlorine unites with all other metals present except the platinum group and converts them into chlorides before it attacks the gold.

The impure gold is melted in a clay crucible glazed inside with borax, and whilst still in the furnace a current of chlorine, generated in the usual manner by the action of hydrochloric acid on manganese dioxide, is passed by means of a clay tube through the liquid mass. Some of the base metals present pass off as volatile chlorides, but silver, which is the chief impurity, is converted into a fusible chloride which, when the gold has solidified through cooling, is poured off and cast into slabs, while the gold is again heated and cast into ingots.

1237. Model of Miller's apparatus for reducing silver chloride (full size). Received 1878. M. 2713.

This shows the arrangement used at the Melbourne Mint to recover the silver from the chloride slabs obtained in Miller's process for purifying gold (*see* No. 1236).

The slabs of chloride are placed in canvas bags in a bath of sodium chloride between vertical plates of zinc arranged in a wooden vat, care being taken to secure electrical contact between the slabs and the zincs. Electrolytic reduction then proceeds, and in 24 hours the silver is reduced

to the metallic state in a pulverulent form, the particles being retained in the bags whilst an equivalent in zinc is dissolved. Iron may be used instead of zinc.

1238. Sectional model of zinc distillation furnace. (Scale 1 : 4.) Made in the Museum from drawings presented by the Morgan Crucible Co., 1902. M. 3222.

This illustrates a form of natural-draught crucible furnace employed in purifying zinc by distillation, or for recovering the zinc from the scum produced in the desilverisation of lead by the process, invented in 1850 by Alexander Parkes, involving the addition of zinc to the argentiferous lead so as to form a scum or alloy of zinc and lead in which nearly all the silver present accumulates.

The distillation furnace represented is square in plan and built of firebrick with a cover of fireclay slabs, held in a cast-iron frame which can be raised by tackle. The plumbago retorts used are in three parts, the crucible, the hood, and the tube or "allonge" for conveying the zinc fumes to the condenser. The crucible rests on a plumbago stand and brick pier in the centre of the furnace, and the condensation is performed in a pyramidal cast-iron box, with a removable cover and sight holes through which the interior may be examined and the tube cleaned by scraping.

The bottom of the crucible having been covered with pieces of charcoal, the interior is packed full of the zinc scum mixed with 1 per cent. of charcoal powder, and the hood and tube are luted on. The furnace is filled with coke and lighted from the top, but the cover is not placed on the condenser until a reducing atmosphere is created by the evolution of carbon monoxide. The distillation then proceeds, and when completed the condenser is removed, the hood at the same time being lifted and the rich lead in the bottom of the crucible ladled out into moulds. The working of a charge of 490 lbs. takes about 8·5 hours, and the product is about 50 per cent. of rich lead, 30 per cent. of metallic zinc, and 13 per cent. of scrapings, &c.

1239. Sectional model of steel casting house. (Scale 1 : 12.) Presented by Messrs. Naylor, Vickers & Co., 1851. M. 1749.

This forms part of a complete model, illustrating the manufacture of cementation steel in Sheffield in 1850 (*see* Nos. 1231 and 1273–4).

Neither blister nor shear steel is homogeneous, so that to obtain the uniform material necessary for making the finest cutlery, &c., fusion becomes necessary. This requires a very high temperature, as well as considerable skill in melting, but the process was introduced and brought to a practical success by Benjamin Huntsman in 1740, who, after he had prepared suitable crucibles and furnaces for the exceptional requirements, established works at Attercliffe in 1770, where the firm still exists and some of the original furnaces remain.

The furnace is simply a rectangular chamber built of firebrick and ganister, and is usually capable of holding two crucibles. The bottom of the furnace is formed by a grate of firebars, while a side flue at the top communicates with a chimney stack; it is usual to arrange a series of furnaces or melting holes in a row, each with its own stack formed in a wall common to the series, as shown in the model. The common furnace top is slightly above the level of the casting floor, and each "hole" is provided with a removable firebrick cover, so that the crucibles and fuel may be introduced through the top, while the whole of the grates and fires are accessible for cleaning from an arched cellar below.

The crucibles are usually made from a mixture of Stourbridge and Stannington clays, with a small quantity of ground pots and coke-dust; they weigh from 25 lbs. upwards, and hold from 30 to 50 lbs. of steel. The new crucibles are dried gradually on shelves above the furnaces for a

week, and are annealed at a red heat before use in an open fire arranged in one corner of the house. The crucibles are withdrawn from the holes by hand labour, and their contents poured into the ingot moulds shown.

1240. Model of regenerative furnace for crucible steel. (Scale 1 : 12.) Made from drawings prepared in the Museum, 1903. Plate IV., No. 1. M. 3276.

This shows the modification made in the furnaces used for melting steel in crucibles (*see* No. 1239) by the application, for the purpose of reducing the fuel consumption, of the Siemens regenerative principle, which appears to have first been adapted to this work in 1862. Several positions for the regenerators have been tried, *e.g.*, they have been built at the ends of the melting chamber, and at right angles to one side, but the most usual arrangement is as here shown, with the regenerators alongside and below the general level.

The hearth, or melting chamber, is divided by cross walls into from two to ten holes, each accommodating six crucibles. Each melting hole, or laboratory, is so short, except in the arrangement where the regenerators are at the two ends, that it is necessary to mix the air and gas intimately before they enter this region; for this purpose the gas regenerator is placed, contrary to the usual practice with open-hearth furnaces, nearest the melting chamber, and the stream of gas for each hole is brought up through three small ports into the corresponding horizontal streams of air; in addition, the ports on opposite sides are out of line, so as to ensure cross currents. The resulting flame is bent downward by a deflecting arch, so as to be concentrated upon the crucibles, which stand on a bed of coke dust supported on ribbed cast-iron plates, resting on side walls and cooled by an air space left below; these bottom plates have holes in them which are closed by old lids, &c., but allow access to each melting hole for cleaning out the clinker at the end of a week's run, or should a crucible break. The top of each melting hole is closed by a cover, made in three pieces, which are handled by a lever supported on the axle of a two-wheeled bogie, or by a chain from wheels on an overhead rail. The crucibles are lifted, after the gas and air have been shut off, by the "puller out," who uses tongs which partially embrace them, and the metal is poured by a "teemer," who uses a pair of tongs which holds the crucible at right angles to those for lifting; the other pair of tongs represented is for removing the cover of the crucible.

The gas from the producers is brought to the regenerators, and so to the furnace, through a culvert, and the waste gas from the regenerators passes in a similar way to a chimney (not shown). The admission of gas and air is regulated by mushroom valves, adjustable by hand wheels at the floor level, and the currents of air and gas are reversed at intervals by ordinary flap valves moved by levers. The consumption of fuel over extended periods has been found to be about 1 lb. of slack coal to the pound of ingot poured, and owing to the ready control of the temperature the labour of handling the crucibles is reduced, so that the charges melted are from 60 to 80 lbs., and even heavier where plumbago crucibles are used. On the other hand, the first cost of the furnace is greater than that of the earlier type.

1241. Specimens of cast steel. Presented by Messrs. Seebohm & Dieckstahl, 1892. M. 2432.

These illustrate stages in the manufacture of high-temper cast steel. The series commences with Swedish wrought iron, which is changed into blister steel by treatment in the cementation furnace (*see* No. 1231). These blister bars are broken up and melted in crucibles. The crucible steel is cast into ingots, of the size shown by the specimens at the sides, which are afterwards drawn out by tilt hammers to small sections, producing the various tempers of steel shown, in which the amount of carbon varies

from ·75 to 1·5 per cent., but for the higher qualities several remeltings are usually performed. Fractures of ingots of cast steel containing tungsten and chromium are also shown.

1242. Model of retort for distilling amalgam. (Scale 1 : 6.) M. 2718.

The retort, which is of elliptical section, is of cast iron, and is set in brickwork over a coal-fired grate. The pasty amalgam, from the barrel amalgamating machine No. 1196, which after being first strained through canvas bags will contain about 15 per cent. of silver, is placed in iron pans in the retort, the front end of which is then closed by the airtight door clamped on. It is then heated to redness, when the mercury distils off and passes by the curved condensing pipe to a small reservoir; the bullion is left in the pans.

1243. Sectioned model of Belgian zinc furnace. (Scale 1 : 15.) M. 2719.

The process followed consists in the exposure of a mixture of zinc oxide and anthracite coal to a high temperature in a clay retort, from which the metallic zinc reduced then distils.

The fireplace of the furnace is below the ground level: above it is a large chamber of refractory material held together with external tie-rods, and into it the flame plays. The front of the chamber is of iron shelves on which the front ends of the long cylindrical retorts can rest, their further ends, which are closed, resting on corresponding fireclay shelves built into the walls. The spaces at the front end are filled in with clay so as to form a solid wall, and prevent the flame from the fire from passing into the working chamber. Each retort is provided with a separate fireclay cone put into its place after the retort is charged, and to this a wrought-iron nozzle is attached, the latter serving as a condenser for the zinc vapour. On the right hand is an oven heated by the waste gases, and in this the new retorts after careful drying can be baked previous to their being used; now, however, the general custom is to use the gases for the purpose of roasting ore, and to prepare the retorts in a separate furnace.

1244. Models of pots for Pattinson's process. (Scale 1 : 12.) Contributed by the Commissioners for the Exhibition of 1851. M. 1741.

In this process, patented in 1833 by Mr. H. L. Pattinson, advantage is taken of the liquation that occurs when argentiferous lead cools. The alloy that first solidifies contains less silver than that remaining liquid. To illustrate the process three pots out of a series of 10 used at Wanlockhead mines are shown. These are hemispherical, of cast iron, each set over a fireplace. The lead smelted in the hearths (*see* No. 1209) is placed in the centre pot, and melted by a fire beneath the working platform. It is then allowed to cool somewhat, when the "crystals" of lead that are first formed are fished out by means of a perforated ladle (*see* No. 1245) and transferred to the empty pot on the right hand, while the enriched residue is then transferred to the left-hand pot. A fresh portion is then treated and the operation repeated at each pot, a small quantity of very rich silver-lead being obtained from the pot at the extreme left hand of the series, while the bulk of the lead, which passes to the extreme right-hand pot of the series, contains no appreciable quantity of silver. The smaller pots, each with its own firegrate seen immediately in front of the model, are to receive the ladles and to keep them at the same temperature as the pots.

1245. Diagram of Pattinson's process (Scale about 1 : 6), and ladle. Presented by H. L. Pattinson, Esq., 1851. M. 1742.

The diagram shows a row of eight pots, in No. 4 of which the original lead of 10 oz. to the ton is melted. The crystals are ladled continuously to the left and the enriched lead passed to the right, resulting in market lead containing about ½ oz. to the ton at one end and rich lead containing about 75 oz. to the ton at the other end. The method of procedure admits of much variation.

The ladle used is shown; it is of wrought iron 16 in. diam. perforated with holes ·6 in. diam.

1246. Models of ingot moulds. (Scale 1 : 6.) Contributed by the Commissioners for the Exhibition of 1851. M. 1741B.

These are for casting lead into ingots for the market. The moulds are on wheels, and for filling are placed in a circle around a pivoted spout along which the lead is conducted. As each mould is filled the stream of metal is directed to the next, and as the lead in each becomes solid, the mould is wheeled to the stack of ingots and its ingot tipped out. The merchant brand is given to the ingots by means of raised letters cast on the base of the mould.

1247. Models of furnaces for heating vats. (Scale 1 : 16.) Made by Herr J. Schröder, 1868. M. 1041.

These show the masonry settings of (1) a hemispherical and (2) a rectangular copper vat used by brewers and others. On the lowest floor of each building is a fireplace and stoking door; the hot gases are made to traverse a circuitous flue, one of the sides of which is formed by the vat itself. Inspection doors are provided at an intermediate floor, and from these the flues may be cleaned.

REVERBERATORY FURNACES.

1248. Sectioned model of roasting furnace. (Scale 1 : 16.) M. 2698.

This shows a furnace formerly used at Freiberg for roasting silver ores with salt in order to convert the sulphide into chloride for subsequent amalgamation (*see* No. 1196).

It is of the side-fired reverberatory type, with flat bed charged through a brickwork shaft from the floor above. The fumes ascend through two chambers between the roof and the floor, and then through two other chambers with baffle walls to catch the valuable arsenic dust before passing to the chimney.

1249. Sectioned model of reverberatory furnace. (Scale 1 : 20.) M. 2708.

This is copied from the furnace formerly largely used in South Wales for calcining copper regulus.

The regulus, received in a granulated condition, was first dried in the large cast-iron pan resting upon the roof of the furnace. It was then delivered through two apertures on to the flat bed and there spread out by the aid of rabbles. When sufficiently calcined, the material was raked out through apertures seen in the furnace bed just in front of the working doors. Each door was provided with an iron roller on which to rest the heavy iron rabbles, and also with a short chimney to carry any escaping fumes away from the workmen. There was a door just under the flue

leading to the chimney stack by which an inspection of the interior could be made without admitting air to the charge. This particular form of furnace is now almost superseded by furnaces resembling No. 1279, but with larger beds.

1250. Sectioned model of reverberatory furnace. (Scale 1 : 16.) M. 2716.

This model shows the common type of smelting furnace still generally used for the smelting of copper ores. Its general construction is somewhat similar to No. 1249, but as the temperature required is much higher, several differences in detail are necessary. The ore is delivered from a hopper mounted upon a pair of rails immediately above the roof, but this mode of charging has ceased to be generally adopted. The firegrate is much larger than that of the previous example, and is provided with an arched roof. The bed of the furnace is made of refractory sand, is slightly hollow, and is formed upon the top of arches that open into the ashpit, so that air can circulate beneath the bed and cool it. A tap-hole is provided at the side of the furnace on the opposite side to the charging door, so as to permit of the withdrawal of the melted regulus. The roof of the furnace is formed of a flat arch continuous with that over the firegrate, and is provided at the end furthest from the fire with a flue leading to the stack. Immediately under this flue a second working door will be seen, through which the slag can be raked from off the surface of the bath of molten regulus. Moulds are provided at this door to catch the slag whilst other moulds beneath the tap-hole receive the melted regulus.

1251. Model of Cornish reverberatory furnace. (Scale 1 : 12.) Presented by Messrs. R. R. Michell & Co., 1862. M. 1744.

This furnace is used for tin smelting, and as the temperature required is very high, a tall chimney stack is necessary; the furnace is, moreover, strongly built and held together by screwed tie-bars. The firegrate is of the step type of large size, and is arranged under the same arch that covers the bed, while the fire bridge has a narrow tunnel through it to assist in cooling it. Two working doors are provided at the side of the furnace and adjacent to the stack; through these the furnace is charged at the commencement of the process, and through a large working door in the end of the furnace the charge is thoroughly rabbled and the slag withdrawn. The bed is made of fireclay and nearly flat, but slopes to a tap-hole in the side of the furnace opposite the working doors. Beneath these is a large receiver into which the molten tin is collected; the first portion, that is, the part having the lowest melting point, is run from the receiver into a large cast-iron pot or "kettle." This kettle has a fire beneath it to keep the tin fluid, while above is a crane by means of which billets of wood, inclosed in an iron cage, are lowered into the molten metal; the currents of steam and gas thus generated passing through the tin refine it. The refined tin is then ladled out into iron ingot moulds, seen at the back of the model. These furnaces are usually worked in pairs, and the second portion of the tin from this furnace would be transferred to the succeeding charge in the other furnace; the slag receives separate treatment.

1252. Sectioned model of reverberatory furnace for lead smelting. (Scale 1 : 8.) Made by Herr J. Schröder, 1868. M. 1043.

This model, after Karsten, has two flat beds superimposed, the lower one being provided with a firegrate at one side. The lead ores were first heated on the upper bed and then raked on to the lower one, where the roasting was finished. The fume was led into a brickwork chamber containing baffle walls, and then allowed to escape at the roof.

1253. Model of German cupellation hearth. (Scale 1 : 16.) M. 2717.

This model shows a furnace arranged for the oxidation of argentiferous lead at a low temperature, the resulting litharge flowing away in the molten state, whilst the residual silver is allowed to solidify on the bed, and is removed after first lifting off the roof of the furnace.

The foundation is of masonry, provided with air channels to keep it cool, and bound together by iron ties. It supports a shallow bed of brickwork of a distorted oval shape, and is subsequently covered with a layer of marl to enable it to withstand the solvent action of litharge. The roof is an iron "hat" hung from the end of a lever crane, so that it can be readily raised or lowered when required. Its under surface is lined with a mixture of clay and straw, held in place by jagged and bent pieces of iron attached to the framing of the hat. There is an opening at the left-hand side of the furnace through which the pigs of lead are inserted, and a larger opening immediately in front through which the lead oxide or litharge flows, and which also serves as an outlet for the gases. The furnace is heated to the low temperature required by means of a grate on the right-hand side, burning pine wood, which gives a long flame. The oxidation is performed by means of blasts of air coming alternately from two nozzles that project through the wall against which the furnace has been built. These jets also drive forward the molten litharge, and assist the otherwise very feeble draught of the fire. The silver cake produced contains lead, and is far from pure; it is allowed to solidify before the hat is lifted for its removal.

1254. Model of German refining furnace for silver. (Scale 1 : 16.) M. 2720.

This differs in several important respects from No. 1253; the firegrate is larger, the laboratory part or bed is smaller, and the furnace is connected to a chimney, so that the temperature obtained is much higher. There is only one blast pipe for supplying air to the surface of the bath of metal, and the opening for it is close to the chimney. An inclined rectangular shoot, adjacent to the nozzle, is the means by which the small square ingots of rich silver-lead or of impure silver are introduced to the bed, which is of marl. There are two working doors, and one of these, seen near the chimney, is provided with a heavy iron plate beneath it. The furnace is similar in other respects to No. 1253, but, on account of the higher temperature obtained and the more porous nature of the bed, the silver refined by it is purer. The bed is capable of holding half a ton of refined metal.

1255. Model of English cupellation furnace. (Scale 1 : 12.) Contributed by the Commissioners for the Exhibition of 1851. M. 1741A.

This model represents a special furnace, which differs somewhat from the one in general use under the above name. The bed consists of a removable iron frame that can be filled with bone-ash. This bone-ash bed or "test" not only resists the action of the molten litharge, but also absorbs it in a marked degree. The test is placed under a fixed roof, and the excess of litharge is allowed to flow through a hole in the test into a small ladle on wheels placed below. The model represents the iron casting of the furnace only; it is provided with a grate on the left-hand side from which the test is heated, and a nozzle behind for the supply of air, with a working door in front for inspection. The lead is first melted in an extèrior vessel, and allowed to run on to the test in the molten condition from time to time, being continually oxidised, until towards the end of the operation the charge upon the test is nearly pure silver. The silver, when completely refined in

such a furnace, is of a higher degree of purity than that obtained from one with a marl bed. It is either cast direct from the test, or else allowed to cool on the bed.

1256. Sectioned model of puddling furnace. (Scale 1 : 8.) Received 1860. M. 2722.

Wrought iron is obtained from pig iron in the "wet" puddling process by stirring the latter when molten on the bed of a reverberatory furnace with excess of air and in contact with fused oxide of iron, thus oxidising carbon and other impurities.

The model represents a furnace used for this process at Bromford Iron Works, South Staffordshire, in 1860. The casing is formed of ribbed cast-iron plates held together at the top by tie-bolts and at the bottom by a trough. The arched roof, sides, and fireplace are made of Stourbridge firebricks. The bed is lined with refractory substances rich in oxide of iron, such as "bull dog." The grate area, 14 sq. ft., is almost as large as that of the bed. The furnace is fired from a small hole kept closed by coal piled upon the ledge projecting below it. A fire bridge divides the grate from the hearth, the bed and sides of which are made of cast-iron plates supported on columns and cooled by air circulating beneath. The door is suspended from a lever and is used for "fettling," charging the pig iron, and for taking out the finished blooms; for the actual puddling there is a small hole at the bottom of the door. Below this is a tap-hole to let out the accumulated slag or "tap cinder" at the end of the operation; normally it is closed with sand. The waste gases are led by a flue to a chimney stack of brick, bound with angles and tie-bolts, and supported on cast-iron columns. It has a damper on the top by which the heat and the nature of the atmosphere on the hearth are regulated.

The charge was 4 cwt. of white iron, which required 1·25 hours to work off. 1·25 tons of coal and 1·1 tons of pig iron were required to produce a ton of puddled bars.

1257. Sectioned model of improved puddling furnace. (Scale 1 : 12.) Lent by Jeremiah Head, Esq., 1876. M. 1423.

This form of puddling furnace was patented by Mr. Head in 1871. The object of the arrangement is to utilise the heat in the discharged gases, by causing them to heat the air supplied to the furnace grate for the combustion of the fuel.

The furnace shown is of the usual construction, having a cast-iron bed lined with oxide and silicate of iron, and the masonry strengthened by external cast-iron plates. The waste gases from the hearth pass into an enlarged stack carried on columns and terminating in an ordinary stack or iron-cased chimney. The enlarged portion of the stack is divided by a vertical wall into two flues, one of which is clear and passes the gases upwards, unless it should be closed by the horizontal damper moved by rack and pinion; the other chamber also communicates with the stack, but contains cast-iron pipes standing on a divided box. Into one side of the box air is forced by an external steam-jet blower, and this air in traversing the pipes is heated to about 340 deg. C.; it then passes along a pipe at the back of the furnace into the closed ashpit. A portion of this heated blast is introduced through tuyères into the space above the fuel, while some is blown downwards upon the fire from orifices in a bridge pipe of brickwork built in the crown.

It is stated that the consumption of coal in this furnace averages about 0·63 ton per ton of puddled bar produced, or about one-half of the quantity required by the earlier forms. The steam for the jet may be supplied by a vertical boiler placed in the stack, an alternative arrangement which is also shown.

1258. Model of furnace for re-heating blooms. (Scale 1 : 12.) Received 1862. M. 702.

The furnace is supported by a complete casing of iron plates, the firegrate is large and the heating rapid. The bed is flat and lined with firebricks set on end whilst the roof is arched longitudinally; no preparation is made for keeping the bed cool by the circulation of air beneath it, but the fire bridge is protected in this way. The working door is of sufficient size to admit the largest pieces of metal that are to be heated, and beneath the door is an aperture through which the slag, resulting from the action of the iron oxide upon the sand bottom of the furnace, flows away. The door itself is of iron, usually lined with brickwork, and is opened by a lever attached to the framing of the furnace. The chimney stack is supported by four cast-iron columns and an entablature, so that the repairs to the furnace can be executed without interfering with the stack; a damper for controlling the draught is fitted on the top of the stack.

1259. Sectioned model of re-heating furnace. (Scale 1 : 12.) M. 2695.

This "balling" furnace is used for raising to a welding heat the "piles" built up of puddled bars, previously to hammering or to rolling into merchant iron. It closely resembles the puddling furnace in construction, but has a flat bed made of sand on a course of firebricks resting on cast-iron plates. The bottom slopes slightly towards the chimney, below which there is a tap-hole for the cinder. The piles are charged on a "peel," and when heated are withdrawn by tongs.

1260. Sectioned model of annealing furnace. (Scale 1 : 16.) Made by Herr J. Schröder, 1868. M. 1049.

This is a reverberatory furnace used for annealing or re-heating sheet metal while being rolled. The fuel used is charcoal, burnt in a deep grate at one end of the bed; on the bed are three massive longitudinal iron bearers upon which the plates slide in through a door at the end opposite to the grate. The position of the door prevents any air entering by it from reaching the objects on the bed. The waste gases may pass directly to the stack, which is over the centre of the bed and supported on four columns or, by a damper, the gases may be directed through flues beneath the bed, thence by side flues to the stack, so equalising the heating and saving fuel.

1261. Model of glass annealing furnace. (Scale 1 : 24.) M. 2707.

This represents a reverberatory furnace constructed to give a considerable range of temperature at different parts of its bed; the annealing is accomplished by gradually moving trays containing the objects to be annealed from the hotter to the cooler parts of the furnace. Two fires are provided, one at each side of the bed at one end; the flames from these are carried to the further end of the bed, where they are taken off by a flue that returns them over the crown of the roof and thence to the chimney. Two tracks of rails are secured on the bed and along these travel the trays carrying the objects to be annealed. The trays hook together and are introduced at the fireplace or hotter end of the bed, and are detached after passing through the furnace, on a continuation of the rails at the cooler end; a windlass and hauling chain are provided for each train of trays.

1262. Drawing of gas welding furnace. (Scale 1 : 8.) Presented by Herr L. G. von Celsing, 1862. M. 705.

This shows a reverberatory furnace combined with a solid hearth gas producer designed by Herr Celsing for giving a welding heat. Fuel is

supplied through a double hopper. Air for combustion, warmed by passing through the walls, is blown in above the fire and above the fire bridge. The waste gases escape at the doors.

1263. Model of regenerative gas-fired furnace. (Scale 1 : 12.) Presented by Sir C. W. Siemens, F.R.S., 1863. M. 1743.

The arrangement of a reverberatory furnace fired by the gases resulting from an imperfect combustion of solid fuel (*see* No. 1205) was patented by Messrs. C. W. and F. Siemens in 1861. The model represents the form of furnace to which this regenerative gas-firing was first applied, *i.e.*, for melting plate-glass.

The glass pots are placed on the air-cooled bed of the furnace, and a flame from producer-gas and hot air plays from separate vertical passages, seen at either end of the bed, over and amongst the pots and finally down through the opposite passages. The escaping gases pass through two of the four chambers placed beneath the bed, and then out to a stack. The chambers are full of open brickwork, which by the escaping gases is raised to a high temperature. When one pair of chambers has been so heated, the course is reversed by the aid of suitable valves, the escaping gases delivering their waste heat into the other pair of chambers, while the entering air and producer-gas are separately heated by passing through the pair of chambers just heated. The valves shown in the model are independent and are moved in regular order by the furnaceman at intervals of about half-an-hour. The chambers in which the waste heat is thus recovered are the "regenerators." Owing to the high temperature of the gases before combustion takes place, the furnace temperature is exceedingly high, while the low temperature of the chimney gases results in economy in fuel.

1264. Sectioned model of apparatus for the "direct" production of steel. (Scale 1 : 24.) Presented by Sir C. W. Siemens, F.R.S., 1871. M. 1933–4.

The "direct" process here illustrated is that of the late Sir C. W. Siemens, in which a mixture of iron ore and fine coal is heated in a chamber containing a reducing atmosphere. This chamber, shown on the right-hand side of the model, consists of a lined wrought-iron cylinder capable of being slowly revolved, and known as the "rotator." It is charged at the front end, and when this is done a reducing flame is directed into its interior from two pairs of firebrick regenerator chambers filled with chequer work (*see* No. 1263), one pair of which is brought to a red heat before starting work. The gases and coal then reduce the iron ore to the metallic state, whilst the continual rolling, caused by the rotation of the chamber, collects the grains of iron into a bloom; the foreign matters present form a fluid slag. The rotator being stopped, the slag is tapped out at a special door into a truck placed beneath to receive it, while the bloom, which is of very pure iron, is finally withdrawn through the central aperature and carried to the gas-fired reverberatory furnace seen on the extreme left. A sectional drawing (scale 1 : 16) on the wall further elucidates this part of the process.

This furnace shows the four regenerator chambers below, as well as the reversing valves, all of which are similar to those required by the rotator although grouped differently. Blooms from the rotator are melted down by this furnace in a bath of cast iron, so forming steel, which is tapped and cast in the usual way. A small chamber attached to the furnace on one side of the bed serves as a muffle, in which blooms may be kept hot before charging into the melting chamber.

In the centre of the model is a furnace with a fixed bed formed into one shallow and two deep cavities. Blooms from the rotator may be left on this bed, to drain off the large amount of slag that they contain, before transferring them to the melting furnace.

At the back of the model is Siemens's cascade furnace for melting a bath of oxide of iron in a cavity on the upper level of the furnace bed; the oxide

is afterwards allowed to flow over heated charcoal lying in the ower bed, and is thus reduced. The blooms so obtained could be used in the ordinary open-hearth furnaces.

Although the method was abandoned on the death of Sir C. W. Siemens, it had shown itself very economical in the consumption of fuel, so that the direct manufacture of steel is a subject that continues to command attention.

1265. Sectional model of basic steel furnace. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., from information furnished by Robert Booth, Esq., 1903. Plate IV., No. 2. M. 3279.

This represents a 25-ton open-hearth regenerative steel-melting furnace forming one of a series designed by Mr. Bernard Dawson and erected at the Earl of Dudley's Steel Works at Round Oak. The steel is made from a charge of pig iron, oxide of iron, steel scrap, and lime, which are melted on the hearth of a reverberatory furnace whose bed is covered with a basic lining formed of dolomite or magnesite. The oxygen in the charge consumes the excess carbon in the cast iron, while the phosphorus is removed by the flux formed from the basic lining; an addition of ferro-manganese is, however, made after tapping to ensure the improved qualities that the presence of manganese promotes.

The open hearth of the furnace consists of a shallow rectangular pan of cast-iron plates supported on girders, which permit of the free circulation of air below it to keep it cool, and protected above by a covering of firebrick and the thick lining of basic material which forms the bed of the hearth; the roof over the hearth is formed by a firebrick arch, and the side walls are also of firebrick, but are externally protected by a wrought-iron casing strengthened by vertical rods or buckstaves held together by long transverse tie-rods.

The furnace is entirely heated by the combustion of producer-gas which, together with the necessary air, is introduced through ports at one end of the hearth, after passing over which the gases escape by similar ports and down through the large regenerator chambers beneath the furnace and thence to a flue leading to a stack. The producer-gas is supplied through a gas flue from which it passes under a mushroom valve, regulated by a hand wheel on the charging platform, and past a butterfly reversing valve to a flue communicating with the bottom of the outer and smaller of the pair of regenerator chambers at the end of the furnace. It then ascends through the interstices between the open brickwork with which the chamber is packed and thence through a vertical flue passing to a lower and central port at the end of the hearth. The air for the combustion of this gas enters another flue by a similar mushroom valve, worked from the charging platform, and, passing a butterfly reversing valve, reaches a flue leading to the bottom of the inner and larger one of this pair of regenerators, through the brickwork packing of which it passes to the two upper ports at this end of the hearth. The combustible mixture thus arriving at this end of the hearth burns forming a continuous sheet of flame, which passes along the hearth and through the three corresponding ports at the opposite end and down through the open brickwork into a similar pair of regenerators beneath that end of the furnace, and then through the horizontal flues to the butterfly reversing valves, by which these considerably cooled gases are passed to a flue fitted with a sliding damper controlled from the platform and communicating with the stack which gives the draught and also carries away the products of combustion.

When the furnace has been working in this way for about half an hour the direction of the gases is reversed so that the producer-gas and the air for its combustion are passed through the heated brickwork of the other pair of regenerators, and are thus raised to a high temperature before entering into combustion over the hearth, the rejected heat at the other end of the hearth being similarly absorbed by the other pair of regenerators. This reversal of

the course of the gases is effected by the two butterfly valves arranged beneath the gas and air valves and controlled by levers from the charging platform.

After the heating has been maintained for about ten hours and the charge is ready for tapping, the tap-hole is pierced, so that the metal flows into a hinged shoot which conveys it into a casting ladle mounted on a carriage running on rails on the sides of the casting pit in which the ingot moulds are arranged. The ferro-manganese and any nickel that may be required are added in a heated but solid condition to the metal while it is flowing into this casting ladle. The metal is delivered into the moulds through a hole in the bottom of the ladle fitted with a plug which can be lifted by an external lever. When the whole of the metal has been "teemed" the ladle is turned over by means of worm gear and the slag poured into a cast-iron slag pot, while the slag remaining in the hearth of the furnace is run off by the hinged shoot into another slag pot.

1266. Manganese steel castings. Lent by R. A. Hadfield, Esq., 1888. M. 1960.

These are samples of an alloy, containing much larger proportions of manganese than is usual in combination with steel, to which the name of manganese steel has been given. The proportions of manganese in the samples of billets shown vary from 6·75 to 23 per cent. Samples of castings of manganese steel are shown, and samples of small bars which have been bent cold to show the ductility of the metal. Some of the samples are exceedingly hard.

1267. Diagrams of fluid compressed steel plant. (Scales as shown.) Lent by W. H. Greenwood, Esq., 1890. M. 2341.

The method of consolidating steel by compressing it while in a molten state was introduced and successfully carried out by Sir J. Whitworth subsequently to 1866, the date of his first patent. The actual working of the process on a large scale is confined to Manchester and the Abouchoff Works at St. Petersburg.

The specific gravity of compressed steel is not greater than that of steel from a sound ingot cast in the usual way, but compressed steel forgings have a somewhat higher tensile strength, greater ductility, and are more homogeneous and reliable in character than uncompressed forgings of the same hardness.

The seven diagrams shown were prepared by Mr. Greenwood for a paper read in 1889 before the Institution of Civil Engineers, mainly based on the plant put down by the author at the Abouchoff Works.

Figures 4 and 5 show section and plan of the steel melting and casting department. There are two open-hearth Siemens furnaces, each served by a hydraulic crane and a circular casting pit. If required for compression the steel is taken in a ladle along rails to the press, which is situated near the crucible-steel melting department, from which also other molten steel may be supplied.

Figures 5 and 6 show vertical section and plan of an ingot mould 34 in. diam. It consists of a forged steel casing, about 4 in. thick, supported externally by steel hoops; a trunnion ring is attached for lifting. The mould is lined with narrow cast-iron staves, the back edges of which are chamfered off to leave vertical passages connecting with horizontal grooves across the edge of the staves that serve as vents for the gases.

Figures 16 and 17 are elevations of a 10,000 tons press. It has four steel columns 16 in. diam. secured by nuts to a cast-iron base; the fixed cast-iron head has two rams and cross heads, from each of which hangs a pair of suspension rods coupled to the movable head. The columns are screwed for the greater part of their length with a square thread to lock the movable head in the required position. The press has a single cylinder 50 in. diam. built up as in gun construction and lined with gunmetal.

BESSEMER PROCESS.

1268. Model of Bessemer steel plant. (Scale 1 : 12.) Made by T. B. Jordan, Esq., 1869. M. 1748.

This represents a complete plant as designed by Sir Henry Bessemer for the conversion of cast iron into steel by the process patented and introduced by him in 1856. The change is effected by blowing air through the molten cast iron, thus burning out the carbon as well as the silicon, and so converting the mass into steel. The mechanical difficulties in such an operation were formidable, but the inventor solved them by a series of inventions that have remained substantially unaltered.

The model shows two 3-ton converters (AA) placed on opposite sides of the casting pit, in the centre of which is a hydraulic crane (C) carrying the casting ladle. This crane can be swung round so that the ladle can receive its charge from either converter, and is provided with a bottom tapping hole by which the contents can be run into ingots in a series of tapered iron moulds arranged circularly. Just outside the pit are two hydraulic cranes (DD) for stripping the moulds and lifting the ingots. Opposite the pit are the valves (B), viz., the air valves for controlling the blowing, and the hydraulic valves for controlling the raising and lowering of the converters and the lifting of the ladle crane. On the platform of the ladle crane itself are the handles for the turning gear, for swinging the ladle round to carry the charge of steel from the converters to the ingot moulds, and also the tipping gear for emptying the residue and slag from the ladle; there is also a locking gear to hold the ladle upright.

A pair of vertical engines work two 3-throw sets of hydraulic pumps (E), and a pair of horizontal high-pressure blowing engines (FF) supply the air, which is blown into the metal at a pressure of from 15 to 25 lbs. per sq. in., through the tuyères in the bottom of the converters (*see* No. 1270).

1269. Sectional model of Bessemer converter. (Scale 1 : 4.) Made by T. B. Jordan, Esq., 1869. M. 1748A.

The outside shows the trunnions upon which it turns, and through one of which the blast from the blowing engine is conveyed by a pipe to the blast box at the bottom of the converter. From this chamber the air passes through six small orifices in each of the nine firebrick tuyères up into the charge of molten metal; the smallness of these jets and the high air pressure prevents the metal from flowing downwards into the blast box. The casing of the converter is built up of wrought-iron plates, and lined with a silica compound called "ganister," which is rammed in before the bottom is fixed. In modern practice the bottoms are made separate and interchangeable.

1270. Tuyère for Bessemer converter. Presented by J. Dunnachie, Esq., 1875. M. 1748B.

This is a fireclay tuyère, from Glenboig, N.B.; a number of such tuyères are used in each converter, and the method of fixing them is shown in No. 1269. Through the small holes in the upper end of the tuyère the blast is admitted, and as these holes enlarge as the tuyères burn away a simple means of fixing is employed so that any damaged tuyère can be quickly replaced.

1271. Model of Bessemer steel works. (Scale 1 : 24.) Lent by Messrs. Gjers, Mills & Co., 1891. M. 2370–1.

This shows a Bessemer plant in which the amount of labour and fuel required has been reduced by later improvements. The molten cast-iron is brought in a ladle running on rails to a lift beneath the converter platform. This lift raises the truck with the charge to the higher level, when the

contents are poured into the spout leading into the converter. After blowing, the metal is poured into a ladle carried by a circular crane, from which it is teemed into the casting ladle carried by the central crane of the casting pit. The steel is then run into the ingot moulds in the usual manner, and as soon as sufficiently set the moulds are stripped by one of the small hydraulic cranes and the hot ingots transferred by a similar crane to a soaking pit.

These pits, which were patented in 1882 by Mr. J. Gjers, were first introduced at the Darlington Steel and Iron Works. By their adoption the time and fuel required in re-heating the ingots before rolling, together with the consequent wasting of the metal, are saved. A freshly cast ingot is much hotter in the interior than at the surface, and this unequal distribution of temperature prevented its being worked until it had cooled and been re-heated; but by placing the ingot for some time in a closed firebrick chamber the heat becomes uniformly distributed so that the ingot when withdrawn from this soaking pit is in a fit state for rolling down into billets in the cogging mill shown.

In modern practice soaking pits are arranged for gas-firing, so as to obviate the necessity of having re-heating furnaces for the cold ingots.

A separate sectional model of the soaking pits, to a scale of 1 : 6, is exhibited beneath the model of the general arrangement.

1272. Specimens of Bessemer steel. Presented by Sir H. Bessemer, 1869. M. 1748c.

These are exhibited to show the ductility of the metal when treated cold. They are :—Two billets bent double under the steam hammer; 1 slice off the muzzle of a gun and 1 ditto flattened under the steam hammer; 4 rods 1·5 in. diam. twisted into a strand; 1 bar 2·5 in. sq. twisted into a helix; 1 railway wheel tire flattened into a figure of eight; 1 cup pressed hydraulically from a disc 23 in. diam. by ·7 in. thick; 1 vase made by hammering up sheet metal, the bowl and stem being separate pieces.

HAMMERING, ROLLING, &c.

1273. Model of tilt hammers with heating furnaces (working). (Scale 1 : 8.) Presented by Messrs. Naylor, Vickers & Co., 1851. M. 1749.

This and the succeeding model form part of a complete model illustrating the manufacture of tool steel in Sheffield in 1850 (*see* Nos. 1231 and 1239).

By piling, welding, and hammering, blister steel is rendered more homogeneous and improved in quality, the product being known as "shear steel" from its having been originally used for making shears for woollen cloth.

The form of tilt hammer represented has a steel-faced head, weighing from 120 to 500 lbs., wedged on to a wooden shaft, which is hooped with iron and provided with a cast-iron trunnion hoop by which it is supported on brasses, adjustable in vertical standards by folding wedges. The tail of the hammer shaft is depressed periodically by a number of tappets projecting from a wheel on a shaft rotated by water or steam power, so that from 150 to 350 drop blows are made per minute, while the workman advances and turns the heated bar upon the anvil as the work proceeds. To diminish vibration, the anvil usually rests on a wooden block, hooped with iron and bedded in the heavy masonry foundation.

The furnace used for heating the bars is of a construction which forms a link between the open forge and the reverberatory furnace, and is known as a hollow fire. It is simply an enclosed chamber partially filled with coke and supplied with a forced blast, so that when a bar to be heated is inserted

in the space above the fire the fuel does not come into actual contact with it. The products of combustion escape through various openings and are carried off by a hood above, which in the model is shown covering two furnaces.

(N.B.—These furnaces are in the model shown nearer the hammers than they would be in practice.)

1274. Model of rolling mills, with heating furnaces (working). (Scale 1 : 8.) Presented by Messrs. Naylor, Vickers & Co., 1851. M. 1749.

Squeezing between rolls is the most rapid method of reducing a slab of iron or steel to the form of plate or sheet metal, and nearly all other materials possessing the necessary qualifications for standing the treatment are also reduced in this way. In 1784, Henry Cort, by the introduction of grooved and collared rolls, vastly increased the value of the rolling mill, as he thus enabled it to prepare round and flat bars, together with the other numerous sections since employed as rails and girders. In bringing a mass of metal from a large to a smaller section, working under a hammer appears to be most beneficial, but the greater rapidity and economy of the rolling process renders its use almost universal, except for the highest qualities of cast steel. The rolls used in the preliminary forging of heavy masses of iron and steel have rolls of from 4 ft. diam. downwards; but the mill here represented is of a lighter type, as it is only intended for treating crucible cast-steel ingots (*see* No. 1239.)

In this plant the engine (not shown) is placed between the sheet mill and the bar mill, and the lower line of rolls in each mill is directly driven, while the upper line is driven from it by pinions arranged in stands or housings at each side of the engine. The distance between the rolls is adjusted by screws through the top of the housings, which limit the amount to which the top roll may rise when the bar or plate is passing beneath it; to allow for this vertical play, the ends of the rolls are made square and are connected by a short square shaft which is coupled to the adjacent ends by loosely-fitting cast-iron muffs or boxes which, while giving the requisite freedom, also protect the rolls in case of accident, since these inexpensive boxes will break before a roll is injured.

The sheet mill has a single stand of rolls, 16 in. diam., while the bar mill has four stands of rolls of 9 in. diam., for preparing round, square, and flat sections; in front of these rolls is a table for supporting the end of a bar before passing it into the rolls, and for some of the sections a directing guide is clamped to the table for ensuring the entry of the rod into the intended groove. With only two rolls in a housing it is usual, after a bar has passed between the rolls, to bring the end back over the top and then pass it in the original direction through the next set of grooves or rolls. In dealing with large sections it is more usual to reverse the engine, so that the bar or plate is given its next passage while entering from the opposite side; the same result is also obtained by having three rolls, the first pass being through the lower pair and the return through the upper pair, without reversing the engine.

Near the rolls is shown a shearing machine, also driven from the engine, used for cutting bars into lengths for piling and for cropping the finished rods.

As the steel can only be successfully and economically rolled at a red heat, it is necessary to have furnaces near the mill for heating the material, or for re-heating it, should it cool too much during the rolling process; these furnaces are here arranged in pairs with a common stack, one pair being for heating piles of bars, while the other is for sheets.

(N.B.—The re-heating furnaces are shown nearer the rolling mill than they would be in practice.)

CHEMICAL MANUFACTURING PLANT.

A few chemicals, such as bay-salt, potashes, saltpetre, and hartshorn, obtained almost directly from natural sources, have long been known, but the synthetical preparation of substances, in most cases entirely new, together with the appliances used, have been almost altogether the growth of the last 160 years.

Sulphuric Acid may be considered the most important chemical manufactured, as it is used in the preparation of so many other industrial compounds. As oil of vitriol it was prepared by the alchemists from the sulphates of copper, iron, or zinc. Common sulphuric acid is known to have been prepared in this country about 1740 by Joshua Ward, who patented the process in 1749. He employed a glass globe as large as could be blown; the globe with a little water in the bottom was heated in a sand bath. Supported above the level of the water was an earthenware dish for the mixture of sulphur with one-eighth its weight of saltpetre; this was ignited by a hot iron and the globe stoppered. After several repetitions the resulting dilute acid was concentrated by evaporation. Dr. John Roebuck, in 1746, adopted a leaden chamber instead of the glass globe, and in 1749 erected works at Prestonpans. In 1774 steam was first turned into the chamber during combustion, and the process was finally rendered continuous in 1810. The Gay-Lussac tower was introduced in 1827 (*see* No. 1276). The necessity of roasting pyrites before reduction caused it to be used instead of sulphur in 1818, but it was not till 1838 that its use became general. The "chamber" acid, if required, is concentrated by evaporation (*see* Nos. 1277–8).

The chamber process is, however, no longer the only one employed, as methods of directly combining atmospheric oxygen with sulphur dioxide by exposure to finely divided platinum are now commercially successful; by these means acid of any desired strength can be obtained directly.

Alkali Manufacture.—In the middle of the 18th century the insufficiency of the supply of potashes (potassium carbonate), used with fat for soap-making, &c., was severely felt. About 1790 Nicolas Leblanc brought out the indirect saltcake process for the manufacture of soda from common salt (*see* No. 1280). Enormous quantities of objectionable "alkali waste," containing practically all the sulphur from the saltcake in the form of calcium sulphide, are made. Processes are in use for recovering the sulphur.

A more recent and direct method of manufacturing soda is by the ammonia soda process, which depends on the fact that when carbon dioxide is passed into a solution of common salt in aqueous ammonia a double decomposition occurs and bicarbonate of soda is precipitated. This process was patented in

1838 by Messrs. H. G. Dyar and J. Hemming, but it was not till 1863 that, chiefly owing to the work of M. E. Solvay, it was commercially successful. The only waste is calcium or magnesium chloride; even this can be decomposed, so making the process theoretically complete.

Hydrochloric Acid.—The commercial acid is obtained as a by-product in the first stage of the Leblanc process (*see* No. 1280), which for this reason is enabled to hold its own with the simpler ammonia soda process. Prior to the Alkali Act of 1863 the gas was allowed to escape into the atmosphere with most destructive effects on vegetation. It is now found possible and economical to condense 99 per cent. of the gas by water in coke or brick-filled towers.

Bleaching Powder is prepared by exposing to the action of chlorine gas dry freshly-slaked lime in a layer on the floor of a large chamber. The gas is prepared by heating manganese dioxide with hydrochloric acid; the manganous chloride remaining in solution after the chlorine was given off was formerly thrown away, but is now recovered by Weldon's process (*see* No. 1282). In the later Deacon process the hydrochloric acid gas is taken direct from the saltcake furnace to a tower, where it passes with air over heated bricks impregnated with copper sulphate, which assists the oxidation of the hydrochloric acid, leaving chlorine diluted with nitrogen. For absorbing the chlorine the lime is exposed in thin layers on shelves in very large chambers connected in series (*see* No. 1283).

Nitric Acid is prepared by the old method of distilling saltpetre with strong sulphuric acid in iron retorts and condensing by bottles in series. Improvements in the condensing apparatus enable acid of the highest strength only to be obtained (*see* No. 1284).

Ammonia.—The chief source of this gas is as a by-product from bituminous coal in making illuminating gas (*see* No. 1674), coke, pig iron, and producer-gas (*see* No. 1208). It is absorbed by a spray of water or acid in a scrubber; the ammoniacal liquor is boiled with milk of lime, and the ammonia evolved is absorbed by sulphuric acid to give the sulphate, or by hydrochloric acid to give sal-ammoniac; in both cases these salts are crystallised by evaporation. Their chief use is in the preparation of chemical manures.

1275. Model of sulphuric acid plant. (Scale 1 : 16.) M. 1746.

This model shows the type of plant in use about 1850 for the manufacture of sulphuric acid. Sulphur was burnt in the arched brick kiln, the bed of which was partially covered with a cast-iron plate; this had beneath it an air space which cooled it sufficiently to prevent sublimation of the sulphur. The supply of air was regulated by using the charging door as a damper. Nitre pots, to supply the necessary nitrous fumes, were placed by means of

tongs amid the burning sulphur, and the mixed gases, together with some steam, passed off to a large cooling chamber in which the sulphuric acid formed condensed. The chamber was framed in timber, lined with lead, and to increase the cooling action was supported on pillars.

1276. Model of sulphuric acid plant. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., 1890. Plate IV., No. 3. M. 2920.

This represents a modern plant for the manufacture of "chamber acid" of specific gravity 1·5 to 1·6 (60 to 70 per cent. H_2SO_4), while by further concentration during the process a considerable quantity of acid of specific gravity 1·7 (78 per cent. H_2SO_4), or "brown oil of vitriol," is also prepared. Both products are commercial articles, but if a stronger acid is required (95 to 96 per cent. H_2SO_4) it must be concentrated in a separate plant (*see* Nos. 1277–8.)

The views of chemists as to the reactions in the process differ in detail, but the general changes taking place are as follows :—

Sulphur dioxide (SO_2), prepared by burning sulphur or a sulphur compound, is mixed with air, steam, and nitric acid vapour (HNO_3) with the result that sulphuric acid (H_2SO_4) is formed. In these reactions an oxide of nitrogen derived from the nitric acid takes part and reacts repeatedly in the formation of additional sulphuric acid without itself being consumed, the slight loss experienced being due to causes resembling leakage. The steam and the oxygen from the air combine with the sulphur dioxide to form the sulphuric acid; but this union only takes place in the presence of the nitrogen compound.

In the plant represented, the sulphur dioxide is prepared from iron pyrites (FeS_2), which, after being crushed to the required size by an ore-breaker, is roasted in the **pyrites burners,** of which there are 18, arranged back to back in two rows with a common flue along the top. There is also to each burner a damper, stirring door, and ashpit door, and the charging is effected in rotation through the front doors; the whole burner is built in brickwork, cased with cast-iron plates held by tie-rods.

The nitric acid vapour is supplied by the action of sulphuric acid on Chili saltpetre ($NaNO_3$) in the **nitre ovens,** which are arranged in the flues from the burners and provided with a charging hopper above, and a spout for running out the resultant fused "nitre cake" (Na_2SO_4). The mixed gases, now at a temperature of 340 deg. C., pass into a combining chamber, whence they pass to the base of the **Glover tower,** which is a vertical shaft 30 ft. high by 9 ft. diam. packed with flints over which some chamber acid and nitro-sulphuric acid from the Gay-Lussac tower are allowed to trickle; the uniform distribution of these is effected by a system of leaden pipes fed by a Barker's mill, leading from a divided tank above. The function of this tower is, by the high temperature of the burner gases, to evaporate some of the water from the chamber acid, thereby concentrating it, while the steam driven off breaks up the nitro-sulphuric acid and restores the nitrous fumes to the leaden chamber; the conversion of the gases into sulphuric acid takes place within this tower more energetically than anywhere else. This concentrated acid, in which form the whole product of the plant may be obtained, is run off to a series of water-cooled troughs, and finally to a receiver or storage vessel.

The gases leaving the top of the tower are at a temperature of 75 deg. C., and are passed directly to the **leaden chambers,** of which there are three, each 132 ft. long, 20·5 ft. wide, by 16·5 ft. high, consisting of a wooden framing lined with thin sheet lead, which, to prevent unequal wasting through galvanic action, is joined throughout by fusing together the edges of the plate by a gas blowpipe; the chambers are provided with windows in the sides, manholes, and gauging recesses at each end, and safety valves above. The whole group is carried on posts so as to allow a free circulation of air. The gases, together with a supply of steam, pass through the chambers successively, forming and depositing in them the weak solution known as chamber acid.

The gases leaving the chamber are passed through a long leaden pipe to the base of the **Gay-Lussac tower,** in which the nitrogen oxides remaining in them are absorbed by exposure to strong sulphuric acid. The tower is 51 ft. high by 7 ft. square, and is packed with coke over which acid from the Glover tower is distributed by a Barker's mill. The remaining gases, chiefly nitrogen, are led to the tall chimney which creates the draught for the whole process as well as that required for the steam generator.

Between the boiler and the kilns are generally arranged the pumping engines and reservoirs for distributing the chamber acid and supplying the overhead tanks of the Glover and Gay-Lussac towers.

1277. Model of plant for concentration of sulphuric acid. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., 1892.

M. 2922.

This plant is for concentrating sulphuric acid by the intermittent process in glass retorts.

Chamber acid (*see* No. 1276) is supplied by a pipe at the left-hand side to the first of a series of shallow lead pans with movable covers. These pans are placed on the top of the flue which leads away the products of combustion from the furnaces used for heating the glass retorts, in the right-hand part of the building. Each successive pan is arranged at a lower level than the preceding, and the diluted acid flows from one pan to the next, and is finally delivered into a lead-lined tank, leading from which is a lead pipe to which are attached smaller lead pipes corresponding in number with the glass retorts. These latter pipes are bent down when required to supply the acid to the retorts, as shown at the four retorts on the left. The partially concentrated acid thus filled into the glass retorts is then boiled therein, and the vapour, mainly consisting of steam, sulphurous acid, and a relatively small quantity of sulphuric acid, is carried off through the movable glass retort heads to the condensing pipe which runs along the outside of the building. The vapour condensed in this pipe drains into a tank at the chimney end of the building. The remaining gases pass to a tower containing coke, the upper part of the tower being connected by a pipe with the chimney. The object of this is to condense the small quantity of acid which would otherwise escape into the air. Each glass retort is placed on sand in a cast-iron pan sunk into a furnace, a separate one being provided for each retort. The stoking is done from the outside of the building, and the process is inspected through the small windows, so as to avoid draughts which are destructive to the hot retorts. When the concentration is completed, the acid is siphoned off into a set of glass cooling vessels in cast-iron pans at a lower level, and from these, when cold, it is siphoned off into carboys placed on hand trucks. The cost of each glass retort is 1*l*.

1278. Model of plant for concentration of sulphuric acid. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., 1892.

M. 2923.

This plant is for concentrating sulphuric acid by the continuous process in platinum retorts.

Chamber acid (*see* No. 1276) is supplied to a tank at the right hand of building, and is delivered in a small stream to the first of a series of shallow lead pans with movable covers, arranged and heated similarly to those in the preceding plant. It is then delivered into a tank, whence it is allowed to flow in a regulated quantity to a shallow platinum pan with a water jacketed leaden cover; thence it passes to a similar pan at a lower level and from the latter to a still made wholly of platinum, from which it flows to a platinum cooler immersed in water, and finally to a cooler consisting of a number of lead pipes immersed in a trough of water. A pipe from this latter cooler conducts the concentrated acid to a distributing trough, whence it is run into carboys placed on a truck running on rails, or occasionally

into large cast-iron vessels for railway transport. The vapour from the shallow lead pans is conducted to the chimney by an earthenware pipe running along the back of the building. The vapour from the two shallow platinum pans is condensed by passing through a worm immersed in water and falls into the sink; that from the platinum still is similarly condensed, and is delivered to the sink, where its specific gravity is tested by a hydrometer to ascertain whether the desired amount of concentration has been attained. The flow of vapour to the first-named worm is assisted by a pipe leading to the chimney. The condensed acid is led from the sink to a well, whence it is pumped by hand to the tank above to be re-treated. The plant is kept working day and night, and is attended to by one man. The consumption of coal is much less that in the glass method shown in model No. 1277.

1279. Sectioned model of black-ash furnace. (Scale 1 : 12.) M. 1747.

The furnace represented is an early form used in Lancashire for production of black-ash—one stage in the Leblanc process (*see* No. 1280), but similar furnaces are used for many purposes, and have beds with as great a length as 60 ft.

The furnace is cased with flat iron bars, and held together with looped tie-rods tightened by wedges. The section shows the construction of the firegrate, the bridge, and the two flat beds, that nearest the bridge being at a slightly lower level than the other. Each bed is provided with a door; neither the bridge nor the beds are air-cooled. The mixture of saltcake, small coal, and limestone was shovelled on to the higher or preparing bed, and, when hot, was transferred by an iron paddle to the lower or fluxing bed, where reaction took place with the formation of sodium carbonate. This was assisted by stirring with a rake. The product was raked out into iron barrows and solidified as black-ash.

1280. Model of plant for the manufacture of soda by the Leblanc process. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., 1894. Plate IV., No. 4. M. 2924.

This model, made from information furnished by the United Alkali Co., illustrates the manufacture of carbonate of soda and various other chemicals by the process introduced by Leblanc about 1790. The first operation is the manufacture of sulphate of soda and hydrochloric acid. Common salt is placed in a cast-iron "salt pot" heated by a furnace below, and to this a quantity of sulphuric acid is added. When about three-fourths of the decomposition has taken place the charge is pushed into the "blind roaster," which is a close muffle furnace, and maintained at red heat till decomposition is complete and sulphate of soda or "saltcake" has been formed.

The gaseous hydrochloric acid is conducted through pipes to the condensing tower, and rises through coke with which the stone tower is filled. The coke is kept moist by water from the tank above, passing down in streams through holes in the cover. The solution of hydrochloric acid thus condensed passes through a pipe at the bottom of the tower, whilst steam and waste gases pass away to the chimney at the top.

Carbonate of soda is made from the sulphate of soda by heating it with lime and carbon. Bogies are filled with the saltcake produced in the previous operation, and these, with other bogies filled with small coal and limestone, are raised by a lift to an overhead gantry, and their contents discharged through a hopper into a cylindrical iron chamber (revolver) lined with firebrick. A rotary motion is imparted to this chamber by an engine. It is heated by the passage through it of the flame from a deep fire at one end. The "black-ash" or "ball soda" resulting from this

operation consists of carbonate of soda, sulphide of calcium, and coke, and is run out of the revolver in a molten condition into a series of black-ash bogies, which are drawn along, as each is filled, by a chain and winch. When cold, the contents of the bogies (black-ash balls) are stacked in heaps and broken into lumps for removal by barrows raised by a lift to the level of the lixiviating tanks, wherein the black-ash is dissolved in water warmed by steam. When the solution is saturated, it is run into a well, from which it is pumped to a settling tank. From this tank the solution descends to a shallow iron tank ("salting-down pan"), and is boiled down by the hot gases leaving the revolver on their way to the chimney, the remaining product being crude carbonate of soda. The calcium sulphide and unburnt coke of the black-ash left in the lixiviating tanks form alkali waste, which is removed in railway trucks.

The crude carbonate of soda is raked out of the "salting-down pan" into a "drainer," and, when sufficiently dry, is put into a reverberatory finishing furnace, where it is heated to redness and finally raked out in the form of soda-ash. This is subsequently employed for the manufacture of soda crystals and bicarbonate of soda, the solution from the drainer being used for the production of caustic soda.

Soda crystals are prepared by placing the soda-ash in the perforated cage of a circular tank or "operator," in which it is dissolved in water heated by steam and agitated by a revolving stirrer. The resulting solution is run into a well, whence it is pumped to a settling tank, from which it is drawn off by a swivel-pipe and run into shallow crystallising pans provided with cross-rods on which the crystals are formed. The mother liquor is run off into a well.

Bicarbonate of soda is formed by putting soda crystals in a closed iron chamber, into which carbon dioxide, generated by the action of hydrochloric acid from the condensing tower on limestone in a stone still, is admitted at the top. After some time the contents of the chamber become changed to bicarbonate of soda, which is then removed from the chamber and placed on shelves in a drying house, heated by steam pipes. When dry the material is ground in a mill and packed in casks. The liquor which drains from the bottom of the iron chamber is run away to the mother liquor well.

Caustic soda is prepared from the liquor from the "drainer" of the salting-down pan by running it into a well, whence it is pumped into a "causticizer," or long boiler, through perforated pipes at the bottom. The contents are kept hot by steam. Lime is placed in the strainer, and the liquor, when converted into a solution of caustic soda, is run out by a swivel-pipe, through a trough, into "caustic pans" heated by a furnace below. When the liquor is sufficiently evaporated, the finished caustic soda is run into drums.

1281. Model of chemical works. (Scale 1 : 144.) Lent by Messrs. R. & J. Garroway, 1888. M. 2921.

This represents the Netherfield Chemical Works at Parkhead, near Glasgow, where are manufactured saltcake, soda-ash, sulphuric acid, bichromate of potash, &c. Labels show the purposes of the various buildings.

1282. Model of plant for Weldon's process. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., 1889. M. 2925.

This process, patented by Mr. W. Weldon in 1866–67 and carried out practically in 1868, is for the purpose of regenerating manganese dioxide from the residues left in the manufacture of chlorine for bleaching powder. It depends on the fact that manganous hydroxide is transformed into the dioxide by slightly heated air when excess of lime is present.

The still liquor—a solution of manganous chloride—is run from the three octagonal mud stills (one of which is shown in section) into a circular well, where the free acid is neutralised and ferric chloride decomposed by strong agitation with limestone dust. The liquor is pumped thence into the still liquor settlers on the top of the building, where oxide of iron is deposited. The clear neutral solution is run off by swivel-pipes to one of the circular towers or oxidisers provided with false bottoms. Here it is mixed with 1·6 times the quantity of milk of lime necessary for exact precipitation of $Mn(OH)_2$. The milk of lime is previously prepared in a circular mixing tank at the ground level. In the oxidiser the resulting mixture of manganous hydroxide, carbonate and chloride of lime, is heated to 55 deg. C. by steam, and a rapid current of air is forced through the liquor from below by a horizontal blowing engine. The mixture is run into the mud settlers at a lower level. The clear solution of chloride of lime is run to waste by a pipe at the back, and the manganese mud, consisting of MnO_2 and CaO, is run into the stills there, to be used over again. In the small oblong still, native manganese is used to make up for the inevitable small loss which takes place.

1283. Sectional model of apparatus for exposing granular material to the action of gases. (Scale 1 : 8.) Lent by Henry Deacon, Esq., 1876. M. 1425.

This arrangement, patented in 1875 by Mr. Deacon, was formerly used in his process for producing bleaching powder.

The layer or "wall" of granular material is formed on double frames arranged within a vertical cylindrical cast-iron vessel that may be heated by an enclosing brick furnace. The porous material is distributed on to the wall by a conical hopper and collected from the bottom by a conical cup. The current of gas passes from the outside through the walls to the space within, from which it is withdrawn, or the direction of the current may be reversed. The frames supporting the wall resemble louvres, with the inner and outer laths sloping towards each other. The angle of the laths is greater than the angle of repose of the material, so that, while retaining it as a continuous wall, and preventing any increase in density due to head, it is permitted to flow as the lower layers are discharged.

1284. Model of nitric acid plant. (Scale 1 : 24.) Made from drawings supplied by Oscar Guttmann, Esq., 1907. Plate IV., No. 5. M. 3480.

Nitric acid is prepared on the large scale by the decomposition of an alkaline nitrate by sulphuric acid. There are two stages in the reaction, the latter involving a high temperature:—

$$\text{(i)}\ NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3$$
$$\text{(ii)}\ NaNO_3 + NaHSO_4 = Na_2SO_4 + HNO_3$$

An excess of sulphuric acid is used, so that the reaction is not completed, and the acid sulphate, having a lower melting point than the normal sulphate, flows from the retort in the fused state. This by-product, known as "nitre cake," is used up in the saltcake process (*see* No. 1280).

The defects of the older methods of production lie in the use for condensation of receivers in series; each of these yields acid of different and diminishing strength, contaminated also with nitrogen peroxide and chlorine (from impurity).

The modern plant shown embodies several improvements patented by Mr. Guttmann in 1890–1901, whereby only acid of the highest strength is obtained. The rate of working is about double that of the older type of plant, and the temperature is higher; consequently nitrogen peroxide and chlorine are not condensed in the acid. The space and cost of plant for a given production are also diminished.

The retort is vertical and of cast iron, built up in sections to facilitate repairs. It is fired externally, the gases following a reversed wheel draught to a flue below the ground. Settings are usually in groups of four, to economise heat and space. The iron plate on the top is utilised for drying the next charge of Chili saltpetre (sodium nitrate). A tank for strong sulphuric acid, filled by an air-lift pump from a tank on the ground, is placed on girders above the setting, and has a pipe to each charging hole. Shallow pans, into which the fused cake can be run by a shoot, are placed in a lean-to shed. In the neck of the retort is a self-acting apparatus which admits air to oxidise lower oxides of nitrogen to nitric acid. The old bottle receivers, being deficient in cooling surface, are replaced by a water-cooled vertical worm, built up of straight pipes and bends of earthenware, 9 mm. (·35 in.) thick, which will stand a great range of temperature. To prevent absorption of impurities, the acid should be removed as rapidly as it is formed, so that each bend in the bottom row has an outlet pipe, liquid-sealed by dipping into a trough, with transverse cooling pipes, leading to the pipe which discharges into the main collecting vessel placed near the floor level. The trough is readily removable for cleaning, &c., and has a tap for taking samples. Compressed air, heated by a coil in the flue, can be blown through the acid in the collecting vessel to "bleach" it; air and any gases set free escape into the pipe leading from the worm. The last pipe of the worm leads to a tower filled with earthenware balls, which are used in preference to coke, as that has a reducing action. It is of earthenware, built up of short lengths, each with an internal flange supporting a perforated plate on which are piled hollow balls (*see* sample), which expose a large surface. The acid thus condensed is continually circulated over the balls by an air-lift pump till enriched, when it is charged into the retort. The gases not condensed here are delivered to the chimney flue by a pipe in which is a window whereby the working of the plant can be judged by the colour.

The charge is 2,240 to 2,688 lbs. for each still. An average charge of 2,240 lbs. saltpetre, containing 97 per cent. $NaNO_3$ with 2,576 lbs. sulphuric acid (sp. gr. 1·42 or 79·4 per cent.), yielded 2,297 lbs. nitric acid (sp. gr. 1·42 or 69·8 per cent.). The coal consumption is 280 lbs., and the time of distillation 10–11 hours.

1285. Model of plant for making stannate of soda. (Scale 1 : 12.) Presented by J. Young, Esq., F.R.S., 1851. M. 1752.

This illustrates the several processes in the manufacture of stannate of soda (Na_2SnO_3), used as a mordant in dyeing. Finely-powdered tinstone is fused with caustic soda in an externally-fired iron pan (No. 1), fitted with a rotary stirrer. The product is transferred into a lixiviator (No. 2), where it is dissolved in water, heated by the waste steam from the engine, to separate any ore that may have been unacted on; the liquor is pumped up to a large clarifying tank (No. 3), whence it is run into iron evaporating pans (No. 4). The finished salt is afterwards dried and its water of crystallisation driven off on a hot bench or stove, shown on the outer side of the model. It is then packed in casks.

1286. Model of still for alcohol. (Scale 1 : 12.) Made by Messrs. John Dore & Co., 1904. M. 3313.

Potable spirits consist of mixtures of ethyl alcohol and water, with small quantities of the essential oils to which their distinctive flavours are due; these oils may be derived from the materials used in making the ethyl alcohol, or may be added subsequently. Any material containing starch or sugar may be used for the production of the alcohol; the following description, however, refers to the preparation of whisky from barley.

The barley is freed from dirt by washing, measured into tanks and steeped in water for from 40 to 60 hours; it is then spread upon a cool floor and allowed to germinate or sprout during from 12 to 20 days, while being continually turned over. After this the grain is transferred to a kiln with a perforated tile floor, under which peat is burned to dry it and give a desired flavour. In about 48 hours this treatment converts it into malt, a substance containing an enzyme or ferment known as diastase, which has the property of converting the starch of grain, when made gelatinous by boiling, into sugar.

The malt is now crushed between metal rolls and run, together with two or three parts of crushed grain, into the mash tun, where it is thoroughly mixed with water at about 60 deg. C., so as to produce cane sugar; this mixture is afterwards passed through a mashing machine in which the production of sugar is completed. The resulting sweet liquid, called worts, is passed through a refrigerator and into vats where yeast is added to convert the sugar, by fermentation, into grape sugar, and then into alcohol. The change occupies four or five days and when completed the liquid known as wash is caused to give off its alcohol by distillation; this process is carried out in two or three stages according to the locality, and the still used is shallower in proportion to its diameter but of greater content in the earlier than in the later stages.

The model shows a wash-still or that used for the first distillation, together with the condensing arrangements. The still is of copper, with the bottom 1·2 in. thick in the centre, tapering to the sides and slightly cambered, while the sides are about ·25 in. thick and the top sheets ·12 in. thick. The still is supported round its bottom within a brick setting, having a firegrate in the middle and a circular flue through which the flames from below are led once round the sides in a wheel draught before the gases escape to the chimney; steam heating is, however, sometimes adopted. The still head, which exerts a certain amount of condensing action upon the vapours given off, communicates with a worm coiled in a vat through which cold water flows, so that complete condensation of the distillate is ensured; in some instances the heat from the worm is utilised in heating the next change of wash.

This distillate is called low wines and it contains about 20 per cent. of alcohol contaminated with fusel oil; the exhausted wash remaining in the still is run off and the solid portion utilised as manure. By a repetition of the distillation process with low wines, the first product obtained is a strong spirit called fore-shots, that next given off is pure whisky, while the final portion of the distillate is known as "tailings." The fore-shots and the tailings contain the fusel oil and are known as faints; after much of the fusel oil has been removed from them by skimming they are redistilled.

1287. Model of Coffey's alcohol still. (Scale 1 : 12.) Made by Messrs. John Dore & Co., 1904. Plate IV., No. 6. M. 3314.

The method of continuous distillation and concentration for obtaining the alcohol from fermented liquor by a regenerative system, in which the heat given out by the condensing vapour is utilised in evaporating other portions of the liquor, was first carried out completely in 1830 by Æneas Coffey. In 1833 he patented his process and commercially worked it at Dublin; since then it has become general, as the patent still permits of the direct and economical production on a large scale of spirits free from fusel oil and containing 95 per cent. of alcohol, or 69 over proof.

The still consists of two portions—the analyser, in passing through which the dilute alcoholic solution known as "wash" (*see* No. 1286) is being gradually heated until all of its alcohol has been expelled as vapour, and the rectifier, in which this vapour is selectively condensed in a series of chambers of gradually decreasing temperature, cooled by the wash on its way to the analyser, thereby at the same time utilising the heat abstracted.

The analyser is a rectangular column built up of pine timbers, 4 to 5 in. thick, closely jointed and held together by tie-bolts, and is divided into

horizontal compartments, with cleaning doors at alternate ends, by 22 copper diaphragms or plates. Each plate is provided at one end with an overflow pipe projecting 1 in. above it, and extending downward into a cup or liquid seal on the plate below, so that the wash introduced at the top of the column shall evenly distribute itself over the whole of the plates as it descends. At the base of the column steam of from 4 to 10 lbs. pressure above atmosphere is supplied, and this is allowed to bubble up through the shallow layers of wash by a large number of small holes with which each plate is perforated. In this way the vapour from each layer of liquid is directly passed through the somewhat cooler layer immediately above it, so that some of its less volatile constitutents condense therein, thus heating the liquor and at the same time enriching it by the continuous transference of alcohol from the lower to the upper layers of wash. By the time the wash reaches the lowest chamber, where the steam is entering, its temperature has become so high that all of the alcohol has been expelled; the vapour that reaches the top of the column is, however, correspondingly rich in the volatile constitutents of the wash.

The rectifier is a similarly constructed rectangular column, but has 32 compartments, which are somewhat shallower than those of the analyser and are traversed by the horizontal coils of a continuous copper pipe. The vapours from the top of the analyser are introduced at the bottom of the rectifier, while the cold wash yet to be treated enters the internal pipe-coil at the top, the flows being in the opposite directions. By the cooling action of the pipes the vapours are condensed into liquid, which, in descending through the perforated plates, is continually reaching warmer zones and thereby undergoing selective re-evaporation, with the result that the less volatile alcohols, together with the water, descend to the base of the column, while the cooler liquid and vapour are continually being enriched.

The upper fifth of the rectifier is separated from the rest of the column by a solid plate, or diaphragm, provided with a special orifice so that the liquid accumulating by condensation above it can be separately drawn off; the liquid from the bottom of the column is also separately collected, while the uncondensed vapours reaching the top are led off to a coil in a refrigerating tank, after passing through which any remaining gases are delivered into the atmosphere. The liquid from the base of the column consists of water and the higher alcohols constituting fusel oil, and under the name of strong faints is collected in the hot faints receiver; while the liquid from the solid diaphragm, or spirit plate, is almost pure alcohol with about 5 per cent. of contained water, and is passed through a cooling worm and then stored in the spirits receiver. The vapour condensed in the external refrigerator is chiefly aldehyde, and under the name of weak faints is collected in another receiver, from which it is removed for mixing with the next charge of wash; the hot faints are, however, after skimming, being continuously pumped back to the top of the analyser, where they again mix with the entering wash.

COTTON MACHINERY.

Cotton is the cellular hair found round the seed of a family of plants growing in temperate and tropical climates. The individual fibres vary from ·5 in. to 2 in. in length and have a silky lustre, which is, however, lost during the severe treatment of manufacture, but it can be regained by a special finishing process. The length of the fibre is a most important quantity in determining the value of the cotton and is known as its "staple." Under a microscope it appears like a twisted

ribbon with thick edges tapering from the seed to the free end; the diameter varies from ·302 to ·000143 in, and there are from 300 to 500 twists per inch of length. The irregularity of the edges makes it possible to spin even the short-stapled cotton into yarn by reason of the mutual engagement of the adjacent fibres. Flax fibres have not the same adhering surfaces, and could not be worked into fine yarn, were it not for their great length.

The earliest method of preparing the material was to detach the fibres and twist them together by the fingers into a thread or yarn, and in this way the Hindoos prepared a remarkably fine calico which has not been surpassed by that from modern machinery. The wisp of cotton wool was supported on the end of a wooden stick about 3ft. long, called a distaff, from which the spinner pulled out the fibres and twisted them into thread which, as completed, was wound upon a reel. The one-thread spinning wheel was first used about 1530, and greatly reduced the time spent in twisting the fibres together, but the operation of separating them was still performed by the fingers. To assist in straightening the fibres, hand cards or wire brushes were used, and by such primitive means all the cotton yarn used in weaving was made till the commencement of the 18th century.

The present system of manufacture follows the process adopted by the early workers; but, as the operations are done entirely by machinery, the number of stages has increased, owing to the more distinct separation that has become necessary. A series of labelled specimens is arranged in the collection which shows the cotton as it passes from each successive class of machine (*see* No. 1289).

Cotton Bolls.—The cotton plant or shrub bears a flower which is succeeded by a capsule or pod containing the cotton and the seeds. These pods are plucked by hand, and usually contain about one-third of their bulk of cotton, the remainder consisting of leaves, seed, dust, &c. These impurities are usually removed at the plantation, the process being known as "ginning."

Ginning.—The earliest method of performing this operation was by working the cotton on a flat stone with a bar of iron rolled by the foot, the roller carrying the seed before it and leaving the fibre. The churka (*see* No. 1292) is a machine acting in a similar manner but running continuously. In 1793 Eli Whitney, of Massachusetts, U.S.A., invented the saw gin (*see* Nos. 1294–5), which is the type still mostly used for American cotton; it has circular saws with pointed teeth, which drag the fibre away from the seeds, and revolving brushes that strip the cotton from the saws. The Macarthy gin (*see* No. 1296) is slower than the saw gin, but is preferred for many qualities, as it injures the cotton less; it prepares from 10 to 60 lbs. of clean

cotton per hour, varying with the staple. After being ginned the cotton is packed in bales pressed by hydraulic power, and shipped to the different countries where it is spun.

Opening and Scutching.—When the bales are opened the ginned cotton is found to be much matted together, and is therefore generally passed through an opener, which loosens it by revolving beaters; thence it is carried by an air current along tubes to a scutcher or blower, where it is again beaten. The remaining leaves and other impurities fall through grids, and the cotton fibres are deposited on a wire drum, from which the cotton is delivered in a continuous sheet or lap (*see* No. 1298). When the scutcher was first brought out by Snodgrass at the beginning of last century, it delivered the opened cotton from the revolving beaters on to a travelling apron; afterwards the dust cage and fan were added, and in 1814 Creighton attached an arrangement that delivered the cotton in a continuous roll. Subsequently, Edward Lord introduced the present arrangement with the fan below, and afterwards invented the self-regulating feeder for giving a lap of uniform thickness. It is now the custom to pass the cotton through several of these machines, each taking several laps simultaneously, so as to equalise the product. The scutcher-waste consists of fragments of leaves and seeds together with short fibres of cotton.

Carding.—The laps from the scutcher are fed into a machine called a carding engine (*see* No. 1303), in which the fibres are laid out straight and parallel by brushes of fine wire, known as cards. The earlier cards were about 12 in. by 5 in., one being held in each hand. Subsequently the size was greatly increased and one card was fixed vertically, while the other, which was counterbalanced by a weighted cord, was worked up and down. In 1748 Daniel Bourn patented a carding engine with a revolving cylinder, and several months later Lewis Paul patented another carding machine. Bourn's engine had four cylinders moving in contact with each other, and resembled the roller carding engine of the present day, while Paul's had a roller with 20 transverse fillets on it working against fixed cards in a concave frame and so resembled the fixed flat carding engine. The carded fibres were stripped from Paul's machine by using a stick with needles projecting from it. In 1773 Hargreaves introduced a reciprocating comb for this purpose, and about the same time the carded sheet was contracted into a sliver by passing it through a funnel, whence it was led into a rotating can, as still generally practised. These improvements were combined into one machine by Arkwright in 1775 (*see* No. 1299), and 10 years later he introduced an improved carding machine, which was very like the present roller carding machine except that it had not the self-stripping arrangement for cleaning the cards. This last feature was introduced in 1823 by Archibald Buchanan (*see* No. 1303).

Carding greatly reduces the thickness of the laps and removes impurities and short fibres as "card-waste," which is used for working up into shoddy. The sliver from the carding engine is a round unstranded rope which, in being coiled into the rotating can, is slightly twisted to the extent of one turn in two feet.

Combing.—Carded cotton contains many short fibres which would detract from the strength of the fine yarns and to remove these the combing machine is now extensively employed. The original machine was invented by Heilmann, of Mülhausen, about 1845, and about the same time Lister and Donisthorpe in England invented a similar machine. In the modern comber, usually eight laps of from 7·5 in. to 10·5 in. in width are combed separately in each machine, and the slivers from these combined. As the cotton passes through, the long fibres are carried along and delivered as a uniform sliver in a rotating can, while the short ones are at the same time combed out and delivered in a thin sheet which is rolled up by a coiler. This "comber waste" is afterwards used for making inferior yarns.

Drawing.—This process introduces the important method of drawing by rollers. The lap of cotton is uniformly lengthened by the sliding of the fibres past each other by a regulated amount so that the individual fibres are caused to take up a nearly parallel position. From six to eight slivers are passed through the drawing frame simultaneously and worked into a single sliver so that considerable uniformity is secured by the averaging action thereby introduced. In a drawing frame in which the slivers from six cans are drawn together through four pairs of rollers the speed of the successive pairs would be in the ratio of 1 : 1·5 : 3·75 : 6 ; the fourth pair revolving six times as fast as the first, so that the final combined sliver is of the same count as each of the original slivers, but of six times the length. By the successive passages an amount of extension is gradually attained that, if attempted at once, would break the lap, but the distance between each successive pair of rollers must always be greater than the length of the longest fibres, as the drawing process does not stretch the fibres but simply slides them on each other. The extension or draught is greatest between the second and third pairs of rollers. The drawn sliver is delivered as a coil in a can in front of the machine. The operation of drawing is repeated twice more upon the material, so that the original six slivers going through three drawings have experienced $6 \times 6 \times 6$ or 216 doublings. If eight slivers had originally been placed together the number of doublings would be 512. This method of drawing out the material, by successive rollers revolving at increasing circumferential velocities, is used in every subsequent process in the manufacture of yarn. The first separate drawing machine in which this

valuable invention was applied was Arkwright's lantern frame (*see* No. 1309).

Slubbing, Intermediate, and Roving.—Soon after the invention of the "spinning jenny," which spins with the fine yarn, a similar machine was introduced for drawing and slightly twisting the heavier sliver, and this machine was called the "slubbing billy." As the process is twice repeated on similar machines, before it is delivered as the fine roving, the second process is known as the intermediate, and the latter as roving. The object in all of these is to draw out the fibres into a thinner sliver or roving ready for spinning, and also by continued doubling to obtain still greater uniformity. To give the sliver sufficient strength to withstand the drawings a certain amount of twist is put in by each frame, but it must be as little as possible, owing to its interfering with the subsequent drawings.

The cans from the drawing frames are placed behind the slubbing frame, and two laps are led through four pairs of rollers with a draught between each pair. The combined sliver is then led down one leg of a flier which winds the cotton on to the bobbin, and at the same time twists the sliver, one turn for each revolution. As the bobbin fills, more sliver is wound in for each revolution of the flier, so that the twist would be decreasing, and the strain increasing. To prevent this, many devices have been invented: that used by Arkwright was a friction brake, which allowed the bobbin to be dragged round by the yarn, but the first true differential motion for varying the relative speed of the bobbin and flier as the bobbin filled, was that of Houldsworth. He drove the fliers at a constant speed, while the bobbin was rotated by a shaft, which received its motion through a pair of conical drums and an epicyclic train of wheels. There are many arrangements of differential, or jack-in-the-box, motions now made, but the object is the same in all, viz.: to secure that the slubbing shall be wound on the bobbin at a constant rate without any stretching.

In winding the material on the bobbins it is important to have it uniformly distributed up and down, a requirement that at first was somewhat neglected. In Arkwright's first frames this distribution was performed at intervals by leading the yarn from different hooks placed on the flier, as was done when using the old spinning wheels. In 1772 Coniah Wood gave the bobbins an up and down motion for this purpose, but the heart-cam arrangement for lifting the rail which holds the bobbins, as seen on Arkwright's machine (*see* No. 1311), was a complete solution, and is found in all subsequent winding machinery.

The main difference between the intermediate and slubbing frames is in the size of the bobbins, which decreases as the yarn becomes finer, but the number of spindles is usually from 100 to 200 in each. For counts of yarn up to 20's, the

intermediate process is omitted, but for finer yarns (60's and upwards) many manufacturers repeat the roving operation.

Spinning.—This, the final process in the manufacture of cotton yarn, differs from the earlier drawing processes in the large amount of twist that is given to the thread, which twist greatly increases the strength of the yarn, and the regularity of its surface, but would absolutely prevent any subsequent drawing. The introduction of machinery for this purpose dates from the middle of the 18th century. Lewis Paul and John Wyatt in 1738 introduced the practice of drawing by rollers. In 1767, James Hargreaves invented the spinning jenny, while Arkwright's water frame, the forerunner of the throstle frame, was introduced about 1775. In 1774, Samuel Crompton invented the mule, which was so named from its intermediate position between the spinning jenny and the water frame. He and the other great inventors of the time suffered severely from poverty and mob violence, the one exception being Sir Richard Arkwright, who, though his patents were upset, succeeded in making his machinery commercially successful.

In the jenny, Hargreaves placed his rovings on a moving frame, and ran his spindles in a fixed one, but Crompton placed the spindles on a carriage, which moved to and fro in front of the creel of fixed rovings, fed out by drawing rollers. The carriage, in its outward movement, drew with it the extended rovings, which were being twisted by the revolution of the spindles, and then the finished yarn was wound upon the spindles during the return motion of the carriage. These are the features of the modern mule, which is the only machine by which the finest yarns can be spun (*see* No. 1320).

The throstle frame is a simpler machine, but has a more limited range. In it, the roving passes through a series of drawing rollers, and then down the hollow arm of the flier, which winds it upon a bobbin, and at the same time gives the requisite amount of twist. The machine is generally used for spinning the hard and strong yarns used for warps known as twist.

The ring-spinning frame is a much later invention, which, although unable to spin the finest counts, is of the greatest importance from its simplicity and great output. It was invented in America about 1828, and two English patents of the next year describe a similar machine. In 1834, Messrs. Sharp and Roberts made a few ring frames, but they were not at that time appreciated. About 1868, Messrs. Brooks and Doxey reintroduced the ring frame, which has since been extensively adopted for work previously done by the throstle frame, and for yarns up to 60's count. The ring frame is a development of the throstle frame, the flier being replaced by a steel loop, which travels loosely round a fixed steel ring

owing to the pull of the yarn. The lightness of this flier permits of the very high speed of 8,000 revs. per min. for the spindles. An example of the modern ring frame is seen in No. 1317.

Yarns intended for warps must be stronger than those for wefts and so are given more twist, while the looser wefts give the soft surface to the cloth. The various yarns are described by the spinners by their "counts," thus: 60's means that 60 hanks of such yarn, each hank of the standard length of 840 yds., will weigh 1 lb. Double yarns are described thus: 60's 2, signifying that two single yarns each of 60's count, have been combined in a single thread, so that 30 hanks of this thread would weigh 1 lb. The spinner's long measure is:—

54 inches	=	1 thread.		
80 threads	=	1 lea or wrap.		
7 leas	=	1 hank	=	840 yards.

It is, however, often impossible to obtain the exact count desired, for, in 60's for example, there may be 51 fibres in the cross section, and one fibre more or less makes an alteration of more than one in the count. Hanks of various yarns are shown (*see* No. 1289), labelled with the spinner's numbers, from 60's 2 to 240's 2. Weft yarns, having to be used in a shuttle, are wound up in small cops, while the warp material is usually twisted into skeins as shown. For certain purposes an exceptionally smooth surface is required and this is obtained by singeing off the ends of the fibres, by passing the yarn through a gas flame. This process raises the count somewhat; for instance, 90's may become 95's.

1288. Photographs, showing cotton preparation in India. Presented by Messrs. Dobson & Barlow, 1895. M. 2738.

Six views in the cotton plantation and ginning houses, concluding with the final bale-pressing preparatory to shipment, are shown.

1289. Specimens of cotton, showing stages in the manufacture. Presented by Messrs. McConnel & Co., 1891. M. 2389.

Commencing with the cotton as found in nature, in bolls, the effects are seen of the successive manufacturing operations, viz.: ginning, carding, combing, drawing, roving, and spinning. The waste materials removed by each process are also shown.

1290. Photographs of modern cotton machinery. Presented by Messrs. Howard & Bullough, 1894. M. 2759.

These 12 views show in order the successive machines through which the ginned cotton passes from the opener to the final winder.

1291. Cotton gin. Presented by R. Burn, Esq., 1862. M. 802.

This is a small roller gin, or churka, for separating cotton fibre from the seeds.

The machine has two equal horizontal iron rollers geared together and rotated by hand. The raw cotton is fed from the front table and drawn

through between the rollers to the other side, while the cotton seeds being too large to be nipped by the rollers remain behind, and when stripped fall down through the grid provided between the lower roller and the feeding table. Small rollers are essential in such gins or the seeds would be carried through and crushed. To adjust the distance between the rolls the bearings of the upper roll are each tightened down by a wedge, the wedges being moved simultaneously by a right and left-handed screw connection.

1292. Treadle churkas. Presented by H.M. India Office, 1880. M. 1497–8.

These two churkas are examples of the Indian roller gin arranged for working by treadle, but are possibly both of English manufacture.

In each gin, the treadle by means of a crank drives a large flywheel and pulley, which by a band transmits the power to a small pulley on the axis of the larger of the two rollers. The upper roller is of iron ·5 in. diam., and the lower of wood 1·5 in. diam., and they are connected together by gearing, arranged to give them equal peripheral speeds. Behind each roller is a revolving four-bladed fan or scraper, driven by gearing from the rollers. The cotton fibre is drawn between the rollers, but the smallness of the upper roller prevents the cotton seeds being carried through. The revolving scrapers remove any fibres that may be carried round by the rollers.

In one example the smaller roller is fluted helically to increase its hold on the cotton fibres, and instead of the revolving scrapers a stationary comb is fixed below the lower roller to clean it.

1293. Cotton gin. Made by Messrs. J. M. Dunlop & Co. Received 1880. M. 1499.

This machine is a self-contained roller gin, specially arranged for hand driving, and was patented in 1859. The upper and smaller roller is of metal and finely fluted. The lower roller is of wood, and driven by a belt on its spindle, or by a pinion gearing into a large internally geared spur wheel driven by hand. The rollers are geared together so as to have equal peripheral speeds, and each is cleaned by a stationary scraping blade. The bearings of the upper roller are pressed downwards by springs, adjustable by wing nuts. The smaller fluted roller pulls the cotton fibres off but cannot grip the seeds which, when cleaned, fall down and through the grating.

1294. Cotton gin. Made by W. Jamieson, Esq. Received 1880. Plate V., No. 1. M. 1501.

This is a small hand-power saw gin intended for cottage use. Similar gins have been made almost entirely of wood.

The machine has a horizontal shaft carrying four circular saws, the teeth being of a special form known as thorn teeth. These teeth project to the extent of ·5 in. through closely fitting slots in the back of a hopper, into which the raw cotton is placed. Parallel with the saw spindle is another shaft having on it an eight-bladed revolving brush, at such a distance that the brushes touch the saw teeth. These two spindles are rotated by an endless band which passes over a large pulley driven by hand, and also round a tightening sheave.

The saw teeth drag off the cotton fibre from the seeds in the hopper, and carry it round with them till the revolving brushes are reached, when, owing to the higher speed of the brushes, the fibre is taken from the teeth, and by the air current resulting from the fan action of the brushes is carried out of a delivery spout at the back of the gin. The brushes also touch a fixed ledge of hard wood by which any entangled fibres are released. The cleaned seeds drop out of the hopper through an adjustable slot at its base.

1295. Model of cotton gin. (Scale 1 : 4.) Presented by H.M. India Office, 1880. M. 2739.

This is a model of a saw gin made at the Dharwar factory, India, in 1872. The machine is intended for use in the cotton plantation, and is driven by a belt from a flywheel on an external shaft.

The gin contains 18 fine circular saws, which partly project through 18 slots in the inclined side of the hopper. Further back is a five-armed revolving brush which touches the saws and also the edge of the containing frame. The main belt drives the saw spindle, and from this the brush spindle is driven by a short belt provided with a tightening pulley.

The fibres of the cotton fed into the hopper are pulled from the seeds by the saw teeth, and carried round by them till the revolving brushes sweep them off. They are then carried by the air current created by the brushes out through the large delivery orifice at the back of the machine, the lower side of the delivery passage being in the form of a grid through which dust may fall into a closed chamber below. The cotton seeds remain in the hopper till stripped, when they fall down and escape through an adjustable outlet at its lowest edge. The hopper is carried by hinges at its upper edge so that it can be swung back so as to leave the saws accessible for cleaning.

1296. Cotton gin. Contributed by W. Wanklyn, Esq., 1860. M. 363.

This is a small hand-power machine, on the principle of the Macarthy gin. A large helically-grooved and leather-covered roller is arranged for driving by hand. Below is a cranked shaft driven from the roller shaft, at five times its speed, by a belt. In front of the roller is a stationary blade or scraper, and below is a blade or doffing knife reciprocated vertically by the crank. The raw cotton is fed from the table on to the roller which, owing to its rough surface, carries the fibre round under the fixed blade. The seeds, being too large to pass under, are stopped by this blade and then cleared off by the reciprocating blade, when they fall down through the grid in the table.

1297. Model of cotton baling press. (Scale 1 : 8.) Presented by J. J. Eckel, Esq., 1863. Plate V., No. 2. M. 900.

This model represents a form of press for compressing ginned cotton into bales, and is arranged so that the bales can be securely bound while under pressure, in order that the cotton may not return to its original bulk when the pressure is removed.

The loose cotton is tumbled into a vertical box which has hinged sides; the bottom of the box is formed with ribs, as is also the lower face of the platen of the press working in guides above. The cotton is usually trodden down by men inside, and, when no more cotton can thus be added, the platen is forced down by gearing, so compressing the cotton into a rectangular bale, which is then bound by external bands that can be inserted through the spaces between the ribs of the platen and base; when bound the platen is released, and the bale pushed out by the side doorway.

The press, patented by Mr. Eckel in 1860, has two vertical racks attached to the platen which, by pinion and spur gearing, are simultaneously moved, pawls and rack teeth preventing any running back. When the greatest pressure obtainable by this mechanism is reached, the crosshead carrying the gearing is pulled down by a connecting rod at each end, the other end of each rod inclosing an eccentric sheave; these eccentrics are driven by spur gearing, and so can pull the crosshead and platen downward through a short distance with very great power. Pawls engaging with racks in the side frames prevent the return motion of the platen, so that by this gear the platen is forced down successively by the space of one tooth for each revolution of the eccentrics.

1298. Model of scutching machine. (Scale 1 : 8.) Presented by Messrs. Lord Bros., 1895. Plate V., No. 4. M. 2914.

This is a model of a four-lap scutcher with a single beater. The adjacent photograph of the actual machine shows some details of the gearing that are not fully represented in the small model.

The cotton, which has already been ginned and passed through an opener, is received by this machine in the form of rolled laps; these it has further to clean from seed, leaf, and other impurities, and to deliver in a very regular sheet. As many as four of these laps are supported on horizontal spindles, over a travelling apron upon which the ends of the laps rest. These are, by the apron, conveyed to a small fluted feed roller which delivers them into a chamber within which revolves a two-bladed beater, making 1,300 revs. per min. These blades pull off the cotton in small pieces as it is fed in, and throw it on a fine screen. At the upper end of the screen are two hollow revolving cylinders with finely perforated surfaces; their ends communicate with two air trunks from which air is continually being drawn by a fan arranged in the base of the machine. These air currents carry with them the dust and finer particles, but deposit the cotton on the surface of the cylinders, from which it is drawn off in two laps by a pair of rollers. The rollers compress them into a single lap, which is wound up on a cylinder resting upon two live cylinders with fluted surfaces.

To obtain a cleaner and more regular product, two or more of these machines are generally employed, the cotton going through them successively before it is passed on to the carding engine. The scutcher represented cleans about 250 lbs. per hour, and requires about 4 indicated H.P.

A very important feature in these machines is the "piano motion," patented by Mr. Edward Lord in 1849, by which the speed at which the cotton is fed into the machine is automatically varied, so that the lap delivered shall be of uniform thickness notwithstanding any irregularities that may exist in the original lap. The arrangement consists in a number of levers, placed side by side on a common axis; the short end of each lever presses upon the feeding roller, and between these ends and the roller the cotton is fed. The thicker the cotton the greater the extent to which the lever is depressed, and the total motion of all the levers is proportional to the quantity of cotton being fed in at any instant. From the long arm of each lever hangs vertically a wedge, and between each wedge is an anti-friction ball, the whole series being kept in place by a channel that stretches across the machine. One end of the channel is solid, and the other end is closed by a bar that is connected with a fork that controls a belt running over a pair of opposite cone pulleys. These cones transmit the motion to the feed roller, and when the wedges lift, owing to thick portions of lap being fed in, the belt is shifted so as to diminish the velocity of feed, and thus secure a uniform deposit of cotton on the perforated drums, which are running at a constant speed.

1299. Original carding engine. Received 1860. Plate V., No. 6. M. 357.

This machine, made by Sir Richard Arkwright about the year 1775, is very similar to the cylindrical carding engine invented and constructed by Daniel Bourn, of Leominster, in 1748. The object of the machine is to remove from the cotton any fragments of leaves, seeds, &c., and also to straighten out the fibres by a combing action. This is accomplished by small wire teeth fixed in leather strips upon three cylinders. The cylinders are arranged horizontally with their axes parallel, and by bands are rotated at different speeds.

The cotton, having been previously ginned and beaten, was fed on by hand to the small cylinder, which would now be called the licker-in. Its wire teeth, which are bent or set towards the direction of motion, lay hold of the fibres of cotton and carry them downward and round to the second or main cylinder. This moves in the same direction at the line of contact, and

also has its teeth set in the direction of motion, but its surface velocity is about 80 times that of the licker-in, and this greater speed causes its teeth to take the cotton from the first cylinder, but at the same time by a combing action somewhat to straighten the fibres. The third, or doffer cylinder, has the same direction of motion at the line of contact as the main cylinder, but only one-tenth the surface velocity, and as its teeth are set in the opposite direction to that in which it moves, it takes the cotton from the teeth of the main cylinder.

A reciprocating comb, which receives its motion from a crank on the axis of one of the pulleys, takes the carded cotton from the doffer cylinder and delivers it in strips. This comb was invented by James Hargreaves in 1773.

1300. Carding engine. Presented by the English Sewing Cotton Co., Ltd., 1907. M. 3491.

This machine came from the works of Messrs. Strutt & Belper, where it was made about 1830.

It exhibits advances over the machine of Arkwright (*see* No. 1299) in size, the general substitution of iron for wood and more particularly in the addition of narrow flat cards placed transversely and close to the top of the main cylinder, an improvement of the latter end of the 18th century that greatly increased the carding action obtainable. There are now nine of these flats; originally there were twelve, the remainder having been replaced at a subsequent date by three card-covered rollers for the same purpose, worked by pitch chain from the doffer cylinder. The distance between the flats and the cylinders is adjustable by set screws. The flats are easily detached and were cleaned from fly and waste by the coarse hand card shown on the floor of the case. The cotton is fed in by fluted rollers. The main cylinder, 36 in. diam., is directly driven by fast and loose pulleys from the engine shafting. From the fast pulley is driven also the eccentric and comb for stripping the lap. The doffer cylinder, 12 in. diam., is covered with fillet card put on helically and not in strips and, therefore, gives a continuous lap. Its surface velocity is roughly one-eighth of that of the main cylinder, from which it is driven by spur and bevel gear. The latter is enclosed by wooden frames fixed between the standards and supporting a hinged sheet iron casing. The hand grinder shown—a board with rough emery glued on—was used to sharpen the cards on this cylinder. The width on the wire and of the lap produced is 18 in. The lap is formed into a sliver by a funnel and two rollers.

1301. Model of carding engine. (Scale 1 : 8.) Lent by R. Bodmer, Esq., 1857. M. 8.

This is a model of an arrangement, included in Mr. J. G. Bodmer's patent of 1824, in which two carding engines are placed side by side, and the slivers led through a trough and united into a single lap. Twenty or more carding engines could be combined in this way, the machines being arranged 10 on each side of the trough, and the 20 slivers combined into a single lap. Mr. Bodmer's object in arranging so many carding engines together was to compensate for irregularities in the thickness of the sliver by averaging, but this result is obtained in modern practice by doubling in the finishing lap machine and in the drawing frame.

The cotton has been previously opened, scutched, and formed into a lap. The lap is fed into the carding engine by rollers, and is carded in the usual way by wire cards or combs, carried upon the large main cylinder, the smaller rollers, and the top flats. The last are secured by pegs to the circumference of a ring concentric with the main cylinder, and there is an automatic arrangement, not shown in this model, however, which lifts the flats one by one and takes them to a revolving brush where they are cleaned, and then returns them to their working position.

1302. Model of wire card cleaner. Lent by R. Bodmer, Esq., 1857. M. 7.

This model shows the mechanism by means of which the top flat cards in Mr. J. G. Bodmer's carding engine, patented in 1824, were cleaned. The object sought was to clear the cards of the dust and impurities which accumulated on them while the cotton was being carded.

In this machine the flat which is nearest to the taking-in end of the carding engine, where most of the dirt would be, is turned over and taken hold of by two hooks on a radial arm, by which it is carried past a revolving brush or cleaning cylinder, and being now clean is placed at the other end of the series, or near the doffer cylinder. Thus the clean flat is put where the finest carding is to be done and gradually works its way back to the other end; the frame carrying the flats being, by ratchet teeth, moved through the space of one flat for each one lifted. In the framing there are two grooves concentric with the main cylinder, running the length of the set of flats and connected at each end by radial grooves. The flats move along the upper groove from left to right to be cleaned and put each in its new place, and they return along the inner groove while carding. The mechanism for turning over the flats and taking hold of them is contained in a radial arm, which swings upon the main axis of the carding engine and receives its motion through a crank and connecting rod. The radial arm terminates in a cylindrical piece which serves as a guide for a sliding piece to which one end of the connecting rod is jointed. At the outer end of the sliding piece is a hook for taking hold of a pin on the flat. Another curved piece with a hook at its end for a like purpose is centred on the extreme end of the radial arm. It has a curved surface, upon which a pin fixed to the radial arm moves and gives the last-mentioned hook a motion sideways with respect to the first hook, so as to turn the flat over.

1303. Carding engine. Presented by Messrs. J. Finlay & Co., 1871. M. 1257.

This carding engine, with the first successful form of automatic stripping or cleaning arrangement, was patented by Archibald Buchanan in 1823, and made by him probably at a somewhat later date, as some of the parts are arranged in a slightly different way to that described in his specification (No. 4875, A.D. 1823). Before Buchanan's invention, the cards or combs of wire were cleared by hand of the fly and waste cotton which adhered to them during the process of carding; this was, however, irregularly and unsatisfactorily done, and the invention of a means of doing it mechanically without stopping the machine marked a great advance in the development of the modern carding engine.

The machine is a combined roller and fixed flat carding engine; the main cylinder revolves close to eight revolving rollers, and above them are 12 flats the cylinder, rollers, and flats being all clothed with the usual wire cards or combs. The flats are arranged so that they can be turned over on to their backs, so that the wire teeth are outside, When thus reversed a revolving brush, carried by a counterbalanced radius arm centred upon the axis of the main cylinder, brushes them as it slowly passes backward and forward, and so strips off the accumulated fly and waste.

The flats are supported at each end by a hinge at one corner, the other corner resting upon an adjustable screw fixed to the frame of the engine. A tappet fixed to each flat is acted on by a sliding rod attached to the radius arm, and the lower end of this rod comes into contact successively with a series of pointed cams fixed to the rim of a ratchet wheel. As the radius arm swings round, the rod is thus pushed up, and the flat is raised into such a position that a curved recess upon the head-rail of the radius arm catches a stud on the flat and turns the flat completely over. It is held in position there until it has been brushed, when a rack on the radius arm meets a segmental pinion on the hinge at the other end of the flat, and, gearing in

with it, returns the flat into its working position. The ratchet wheel is turned through the space of one tooth in each oscillation of the arm, so that those flats which lie on the same radius as the tappets on the ratchet wheel will be cleaned in one oscillation, and those between them in the next.

The brush is continuously rotated by a band passing over a pulley on its axis and over another on the main axis, and the radius arm is oscillated by a crank and connecting rod. At the end of its travel furthest from the doffer cylinder, the brush is itself cleaned by a needle frame or comb, the needles taking off the motes and fly; this comb is in turn cleaned by a sliding copper plate, and the strips of card waste fall into a wide box fixed to the back of the machine. The carded cotton is removed from the main cylinder by two doffer cylinders, each cleaned by a reciprocating comb, and then passed through a funnel-shaped orifice delivering into a sliver can.

1304. Kay's wire card-making machine. Contributed by W. Horsfall, Esq., 1860. Plate V., No. 5. M. 360.

This machine is believed to have been made by John Kay, of Bury, about 1750, for cutting, bending, and inserting the wire in the cards used in the preparation of cotton. Previously these tedious operations had always been done by hand, and Kay was the first to make a machine to perform the work. Card-making machines did not, however, come into general use till 50 years later, when Amos Whittmore introduced an improved form.

In Kay's machine the card clothing, which consisted of cotton or linen cloth with a backing of leather, was fixed in two vertical stretching-frames, each capable of sliding vertically in an outer frame, which could move horizontally along the length of the bed. It is a duplex machine, two cards being simultaneously prepared, one in each frame. The main shaft is horizontal, and various cams, by which the following operations are performed, are fixed along its length at different points. The wire is led along parallel to the shaft, and the operations performed by the mechanism are:—

(*a*) Feeding on a given length of wire.
(*b*) Gripping the length of wire which has been fed on.
(*c*) Pricking holes in the card clothing.
(*d*) Cutting off a length of wire.
(*e*) Bending it into a staple.
(*f*) Pushing the staple forward and bending its legs to give the proper set.
(*g*) Moving the stretching-frame into position for the next staple.

The first movement is performed by a jointed frame between two bars of which the wire passes, the arrangement being driven intermittently by a peg on the shaft, and the wire nipped during the forward motion. The holes are pricked in the cloth by piercers fixed at the ends of two levers which swing about joints below; they have a quick motion forward and then fall back again. The cutting is done by a shear blade, moving over a plane face through which the wire passes. When forming the staple, the cut length of wire is held between an arm, which swings vertically at right angles to the main axis, and a steel spring. The arm is moved upward, and enters a recess in the fixed cover plate, just wide enough to admit the arm and the wire, so that the latter receives two short bends and becomes a staple. After this, a part of the arm which slides upon it is pushed forward and carries the staple with it, but the legs being caught in two inclined grooves at the side are bent and so receive the necessary set. Finally, the steel spring, which is thickened at the end, slides further forward than the rest of the sliding piece, and pushes the staple into its place in the cloth. The horizontal feed is given, after each staple has been inserted, by a lever which engages with a rack fixed to the stretching-frames. The vertical feed is given when the end of each row of staples is reached, an arm on the shaft striking a tooth on a star wheel fixed to a pinion which engages with the teeth of a vertical rack at the back of the frame.

1305. Combing machine. Presented by Messrs. Dobson & Barlow, 1894. M. 2725.

This machine represents an improved form of Heilmann's comber. It is used in the preparation of the materials for the higher counts of yarn, and finishes the work of the carding engine by laying out the fibres parallel and removing all dust and short fibres. The cotton, before it arrives at the combing machine, has been opened, scutched, and carded; the slivers from the carding engine have been put through a Derby doubler and a ribbon lap machine, and in this way the cotton is obtained in an even lap from 7·5 to 10 in. wide.

The lap to be combed is placed on the wooden rollers at the top of the machine, and is fed on to the combing cylinder by a pair of rollers which turn intermittently. The combing cylinder, which is as long as the width of lap treated, carries on its surface two sets of teeth arranged in rows, those coming first to the cotton being coarse, but gradually they become finer as the combing progresses. After one set of teeth there is an interval of smooth cylinder, slightly sunk in, then a fluted segment, and another smooth space, then the other set of combs, followed by another smooth space and a second fluted segment.

The feeding rollers by their intermittent motion having delivered a certain length of lap, slightly less than the length of the shortest fibre to be retained, a pair of nipper blades move together and hold the lap, while the teeth on the cylinder comb out the dust and shorter fibres. This being done, a top comb descends and holds the end of the fibres, while the delivery rollers turn backward and bring up to these ends those of the fibres last combed, when a leather-covered roller descending presses them together and the delivery rollers turn forward and remove the combed cotton.

The short fibres are meanwhile carried round by the combing cylinder, from which they are removed by a revolving brush at the back, and a slowly revolving doffer cylinder, with sharp wires projecting from its surface, takes them from the brush. A reciprocating comb strips the doffer cylinder and delivers this comber waste as a continuous fleece, which is wound in by the waste shaft at the back of the frame.

The cycle of operations is completed twice in each revolution of the combing cylinder, which is driven continuously by a pinion on the driving axis. The feed rollers receive their intermittent motion from a pinwheel with two pins, on the axis of the cylinder, engaging with a wheel shaped like a Geneva stop, and giving to the feed rollers a slight rotation twice during each revolution of the cylinder.

The nipper blades, that hold the fibres fed on for combing, are closed by the top blade moving downwards and pressing against the turned-up lip of the lower blade. Motion is received through a lever, which carries the lower blade beneath its centre, and is driven by a vertical rod moved up and down by a crank on a shaft. This shaft is oscillated by a cam on a continuously-revolving shaft, running the length of the frame, and carrying several other cams.

The delivery rollers are worked by a segmental rack oscillated by an arm whose end works in a cam on the cam shaft, and the rack drives a pinion fixed on a shaft which can turn independently of the rollers. A leather-faced friction clutch, opened and closed by a cam on the cam shaft, couples the shaft so that the backing motion of the rollers takes place when the segmental rack is moving upward, and the combed cotton is delivered when it moves downward again. While the combing is going on the friction coupling is open, and when it ceases the friction cones close and the rollers turn back, and then, the ends of the fibres having been pieced up, they turn forward again and deliver the continuous fleece, at the same time drawing the lap for the next combing through the nippers.

The sheet of combed cotton is now led through a small hole in the tin dish in front, and then taken through a pair of heavy rollers. The resulting slivers from each head are joined, and pass together through three pairs of

rollers, and then through a trumpet-shaped tube to a pair of rollers delivering into a vertical cylindrical can carried on a revolving table. The doffer cylinder is revolved slowly and continuously by worm-gearing, driven by bevel wheels from the roller gear at the end of the frame.

The machine shown is shorter than those generally used in cotton factories, having only two heads instead of the usual six or eight; accordingly, there are only two sets of operations going on at the same time, and two laps being combed. The combing cylinder makes 60 revs. per min., while 120 nips are given, and a standard machine of eight heads will produce in one day of 10 hours from 100 to 130 lbs. of combed cotton.

This machine is called a duplex comber because it goes through the cycle of operations twice for every revolution of the doffer cylinder.

1306. Spinning wheel. Received 1860. M. 356.

This is an example of a hand-spinning wheel, once the property of Sir Richard Arkwright, as used at the time when Hargreaves's spinning-jenny and the former's water frame were first introduced.

The fibrous material was held in the creel, drawn from there by hand, and worked up into a thread. This was led through the hollow axis of the flier, over one of the hooks, or hecks, on the flier, and wound upon the bobbin, which was loose upon the flier spindle. There were two bands from a double-grooved flywheel, driven by a treadle and a crank, to two small pulleys of slightly different sizes, one fixed to the flier spindle, the other to the bobbin. The rotation of the flier put twist into the thread, and the difference between the speeds of the flier and bobbin caused the thread to be wound upon the latter. Very fine yarns could be spun with these wheels, as fine as any which can be made with the machinery of the present day, but a great deal depended upon the skill of the spinner, and the output was very small.

Cotton spun by such wheels had not sufficient strength for general use as warp thread, so that warps were usually spun from flax, but Arkwright's machinery by the greater twisting and consequent strength that it gave to the thread rendered the use of cotton general for both warp and weft.

1307. Spinning wheel. Woodcroft Bequest, 1903. Plate V., No. 3. M. 3286.

The earliest appliance for twisting fibres into a thread appears to have been the distaff, which was a stick with a bundle of carded fibres wound on the end; the distaff was held under one arm and a tuft of fibres was drawn from it through the finger and thumb of the right hand by the weight of the bobbin, which was set spinning by the left. The length of thread or yarn thus formed was wound on the bobbin and fixed temporarily while the next length was spun.

The spinning wheel, in which these two operations are performed simultaneously, was introduced into this country in the 16th century, but was used earlier abroad; the small example shown is, however, comparatively modern, dating probably from the latter half of the 18th century, when spinning was a home industry. It consists of a wheel moved by a treadle and crank, and giving motion by bands to two pulleys, the larger of which is attached to a flier, and the smaller to a bobbin loose on the flier spindle. The fibrous material already carded, *i.e.*, laid with its fibres parallel, is held on the distaff, and from this a quantity, regulated in thickness by being passed between the finger and thumb of the operator, is drawn through the axis of the flier, and guided by "hecks" or hooks on it on to the bobbin; as the latter fills, the thread is changed to another heck. The bobbin-pulley, revolving faster than that of the flier, has a motion relative to it and, therefore, winds on the thread, while the rotation of the whole system twists the length of fibres between it and the operator's fingers; to put more twist into the thread there is an alternative pulley on the flier nearer in diameter to that of the bobbin.

1308. Spinning wheel. Presented by W. W. Midgley, Esq., 1905. M. 3427.

This is a portable form of the flax-spinning wheel made by James Webster (*fl.* 1768), of Mardol, a suburb of Shrewsbury.

The distaff and bobbin are supported on a turned spindle in a wooden base with two horns by which it could be strapped to the waist so that the machine could be used by a person walking. The distaff can be clamped at any angle by a wing nut. The flier is driven by a handle and gearing in the ratio of 6 : 1, and the retardation in speed of the bobbin necessary to put in the twist is obtained by the friction of a cord over the bobbin, wound round a peg in the spindle.

1309. Original drawing frame. Received 1860. M. 353.

This is Sir Richard Arkwright's first drawing frame, and was made by him about 1780. It was commonly known as the "lantern" frame, owing to the fact that the sliver-can employed had an opening in the side closed by a door through which the sliver was removed, and so somewhat resembled a lantern.

In this machine the front rollers turn at three times the speed of the back pair, and the sliver is fed on from the back of the machine through a fork which travels to and fro continuously, guiding the sliver to different parts of the rollers. It receives its reciprocating motion from a crank pin on a pulley, turned by bands from the main driving drum, the axis of which is vertical. After passing through the drawing rollers the sliver is led down through a short tube to a pair of rollers attached to the top of a vertical can of conical shape. The can is driven by a band from the main drum, and on its axis is fixed a pulley, from which a band passes over guide pulleys to the pair of rollers on the can, so that they feed the cotton into the can at a definite speed, while the turning of the can puts into the sliver a slight twist.

1310. Original spinning machine. Received 1860. Plate V., No. 7. M. 354.

This machine, made by Sir Richard Arkwright in 1769, shows his first application of drawing rollers to cotton spinning. The roving, wound upon bobbins placed at the back of the frame, was led successively through four pairs of rollers, each pair revolving more quickly than the preceding pair, so as to draw out the cotton to a finer thread. The bottom rollers are fluted and are geared together so as to give speeds in the ratios of 1 : 1·16 : 1·33 : 6·25, so that the last pair is rotated more than six times as fast as the first. Each roller is in four lengths, so that four threads were being prepared simultaneously for winding on the four spindles below. The upper rollers are covered with leather, and were pressed upon the lower ones by pulleys over which small lead weights hung, but these have not been preserved and only the hooks to which the cords were attached remain.

From the drawing rollers the thread passes through a wire guide, placed over the centre of a revolving spindle upon which were carried a bobbin and flier, both of wood. On one leg of the flier hooks or hecks were fastened, and the thread was passed round one of these and afterwards round another as different parts of the bobbin filled. The flier was fixed to the spindle and turned with it, but the bobbin was loose and driven by a twisted worsted band, which was fixed by one end to the sheave of the spindle, and at the other was "put about the whirl of the bobbins, the screwing of which tight "or easy causes the bobbins to wind up the thread faster or slower" (*see* Arkwright's specification, A.D. 1769).

The rotation of the flier, carrying the thread with it, gave one turn of twist to the yarn for each revolution. The bobbin, under the pull of the yarn, rotated in the same direction as the flier, and if it went at the same speed would wind in no yarn. "The screwing of the band," however, put a

drag upon the bobbin, and it wound in yarn equivalent to the number of revolutions that it lagged behind the flier.

The motive power was intended to be that of a horse, and it was applied by a vertical shaft standing on a wooden bracket projecting from one side of the machine, and driven by spur gear from the vertical shaft of the horse wheel. A pulley of large diameter, keyed on at the lower end of the countershaft, turned the four flier spindles by an endless belt, and by a friction wheel drove an upright shaft, which gave motion through crown gearing to the drawing rollers.

This machine could be used only for spinning the hard and strong yarns used for warp. The softer yarns for weft had still to be made by hand, except in one or two places where James Hargreaves's spinning jenny was in use.

1311. Improved spinning machine. Received 1860. Plate V., No. 8. M. 355.

This machine was made by Sir Richard Arkwright about 1775, and is an improvement on his first machine, No. 1310, in having an arrangement for guiding the yarn over the bobbins evenly, and in containing more spindles.

The driving arrangement is very similar to that described in No. 1310. The belt from an external main driving pulley, in addition to turning the spindles, drives two drums, placed on the vertical axes, which transmit motion to the drawing rollers above. Each of these vertical shafts drives four sets of rollers, and there is an arrangement for throwing either shaft out of gear.

There are three pairs of rollers, the top ones covered with leather, and the lower ones fluted, their speeds being in the ratios 1 : 1·6 : 18·4.

The spindles, of which there are eight, are provided with fliers which carry the thread round the bobbins and at the same time twist it, just as in the earlier machine. Regular winding upon the bobbins was secured by the following mechanical means: at the back of the machine, near the ground, is a wooden shaft driven by a belt from the roller gear, and having a cam fixed at each end pressing against a roller fixed in a frame, which swings in trunnion bearings above, and has the lifting rail attached to it in front. This rail has eight plates projecting from it, through which eight spindles pass, and on these plates the bobbins rest. As the heart-shaped cam revolves, the swinging frame or bell-cranks move the rail and bobbins up and down, so that the thread is wound on at different parts of the bobbin in succession. This very important improvement is believed to have been first introduced by James Hargreaves.

Machines of this kind driven by water power were used by Sir R. Arkwright at Cromford, in Derbyshire, hence the name of water frames by which they were known. The throstle frame is the same in principle as this machine, the improvements being chiefly in its details and mechanical construction.

1312. Original wrap reel. Received 1860. M. 352.

This is a measuring appliance, invented and made by Sir Richard Arkwright, for winding yarn into hanks of measured length and convenient for packing. As yarn is sold by weight the price depends largely upon the number of hanks that go to the pound—a quantity known as the "count" of the yarn—and for determining the count this wrap reel is also most convenient.

The reel consists of a 6-armed star turning on a horizontal axis and rotated by a winch handle. From the axis reducing gearing transmits motion to an index moving over a horizontal circular dial, the reading on which indicates the length wound on.

One revolution of the reel winds on 1·5 yds. of yarn and moves the index through $\frac{1}{560}$th of the circle. The dial is divided into seven equal

parts so that one division represents 80 turns of the reel or 120 yds., which makes one "lea" or "wrap." Seven "wraps" make one "hank" or 840 yds., a quantity represented by the index having moved once round the dial.

When reeling to find the count of the yarn, one wrap is wound off and weighed. As there are 7,000 grs. in a pound and seven wraps in a hank, the number or count of the yarn is obtained by dividing 1,000 by the weight of the measured wrap in grains.

1313. Model of drawing and lapping machine. (Scale 1 : 5.) Contributed by R. Bodmer, Esq., 1857. M. 9.

This is a model of Mr. J. G. Bodmer's machine, patented in 1824, for treating the cotton after it has been scutched and formed into a lap; the leading idea of his process was to keep the slivers in the form of lap as long as possible before placing on bobbins.

In this machine two laps are unrolled side by side and pass together through three pairs of drawing rollers, the last pair of which moves at about 12 times the linear speed of the first; then through a pair of pressing rollers which deliver it upon a travelling band. Upon this band are also delivered the slivers from 11 other heads, and the lot passes to a conductor along which it travels to the lap-forming attachment, which is in duplicate. This conductor is pivoted near the end of the travelling band, and when a lap is completed at one side of the lap machine the conductor is slewed round so that it delivers the slivers to the other side; then the completed lap is removed, so that the running is continuous.

The last set of rollers, through which each sliver passes before it reaches the travelling band, is placed obliquely so that each sliver as it comes off is delivered upon the band parallel with the others, without overlapping.

1314. Model of drawing frame. Contributed by R. Bodmer, Esq., 1857. M. 10.

This model represents a form of stretching or drawing machine included in Mr. J. G. Bodmer's patent of 1824.

The lap, which has been prepared in the form of a roll by his lap machine (No. 1313), is placed upon two horizontal rollers which, revolving in the same direction, rotate the lap at a uniform linear speed, and unwind it. The several slivers of the lap are passed together through drawing rollers, by which their length is increased from 12 to 15 times; each passes through a separate hole in a horizontal guiding rail, and they are then wound together into a fresh lap or roll.

As the extension greatly reduces the diameter of the slivers, they cannot form, after drawing, a lap of the original width; so to close them together uniformly, the final lap is wound on a horizontal axis at right angles to that of the drawing rollers, an intermediate directing roller dividing the 90 deg. unequally. The guiding rail is reciprocated longitudinally by a double-grooved cylindrical cam, and to permit of the adjustment of the inclination of the directing roller, it is driven by a universal joint.

Mr. Bodmer intended to place 25 of these heads in one machine and to wind up the 200 slivers so treated in one roll, which was then to be sent on to the throstles or mules. To give strength to the roll, he wound in with the lap a cloth of equal width.

1315. Drawing rollers. Contributed by Evan Leigh, Esq., 1858. M. 362.

These are special constructions of leather-covered rollers for drawing cotton or other fibrous material, as patented by Messrs. E. and G. P. Leigh in 1856–57. Instead of allowing the rollers to turn on pivots, as before, they are made hollow and turn on a fixed spindle; while, in order to lubricate

the bearings, the ends of the spindle are turned down so that the oil used shall gravitate to the larger portion, where it is required, without escaping at the ends and on to the rollers.

1316. Doubling frame. Presented by Sir T. Bazley, Bart., 1858. M. 133.

This is a machine for doubling cotton yarn to form thread for sewing or other purposes. It is similar to a throstle spinning frame, but is without drawing rollers, and is arranged for spinning two yarns into one thread.

The cops containing the yarn are placed in the creel along the centre of the frame, and the yarn for each spindle is led down underneath a glass rod in a trough of water, and between a pair of brass rollers, to a flier fixed at the top of the vertical spindle. From the flier it passes to a bobbin loose upon the spindle, and as the flier rotates it twists the two yarns together, and at the same time winds them on to the bobbin. As the rollers do not feed out the yarn as fast as the flier would wind it on a fixed bobbin, the difference is made up by the bobbin slipping round under the pull of the yarn. The bobbins rest upon a rail which is raised and lowered by heart cams placed below the machine, so winding the thread uniformly on the whole length of each bobbin.

A feature of this machine is the extent to which frictional driving is employed. From the main central shaft two parallel shafts are driven by leather-covered pulleys, and each of these shafts has on it 24 metal discs or friction cones, each driving a leather-covered conical pulley, formed on the base of a flier spindle, no cords or belts being used. The rollers are, however, connected by positive gearing with the driving shaft.

1317. Ring-spinning frame. Presented by Messrs. Dobson & Barlow, 1894. Plate VI., No. 1. M. 2676.

This is a shortened example of a double-geared modern ring frame. It has 48 spindles, but in the complete frame, as used in a cotton factory, there would be about 400 spindles. This machine is designed to spin cotton yarns up to 60's, *i.e.*, yarns of which 60 hanks, of 840 yds. each, would weigh one pound. The cotton is brought from the roving frame in the form of roving wound upon bobbins, which are placed in the creel of the ring frame.

From the three pairs of rollers, which have drawn it finer, the yarn passes through an eye, placed over the centre of a spindle, and is then threaded through the traveller, which is a bent piece of steel wire holding loosely to the rim of a horizontal ring fixed in the traverse rail. The axis of each spindle passes accurately through the centre of each ring, and the front pair of drawing rollers is placed at such an angle that the yarn may be free, from the nip of the rollers to the travellers, thus allowing twist to be put into the whole length. The bobbin is fixed to and turns with the spindle, and by its rotation carries the traveller round with it. The friction of the traveller upon the ring, however, impedes its motion, so causing the yarn to be wound upon the bobbin, while giving it sufficient tension to wind on tightly, and one turn of twist is put into the yarn for every revolution of the traveller.

The traverse rail, which holds the rings, is raised and lowered by lifting pillars, which derive a vertical motion from a heart cam and shaper, connected by chains with levers beneath the frame. The rail is balanced by counter-weights, so that it is easily moved up or down. The main chain of the lifting or traverse rail is gradually drawn in, so raising the mean position of the rail as each conical layer forming the cop is added, but the copping traverse remains constant, and continues to form cones on the bobbin until it is full.

The spindles which carry the bobbins are driven at about 8,000 revs. per min. by cotton bands working on small pulleys on the spindles, from two

tin drums which run the length of the frame underneath. The rings are made of steel or case-hardened iron, highly polished. The plates supported by hinges from the rail, which carries the rollers, are called anti-balloon plates, and are for the purpose of preventing the yarn of adjacent spindles from diverging sufficiently to come into contact. Short fibres accumulate upon the travellers while working, and unless removed would cause increased drag upon the yarn, which would ultimately break. To clean the travellers, short pieces of iron flattened at the ends are fixed into the ring rail, so as just to clear the traveller as it flies round, while scraping from it any adhering fibre.

To prevent grooving of the drawing rollers, the roving is guided to different parts of their length by the following arrangement. The top back roller terminates in a worm, which gears into a wheel containing an eccentric, and this gives a reciprocating motion to a bar having vertical slots, through which the roving passes to the rollers.

A worm on the end of one of the front rollers works a counting apparatus which registers the length of yarn delivered by the front pair of rollers.

Messrs. Dobson & Barlow about 1894 made a ring frame which spun cops upon the bare spindles, instead of on bobbins as in this machine, and 80's yarn was spun in this way. The improvement consisted chiefly in the construction of the traveller, which was much longer than the ordinary form and differently balanced; both forms are here shown for comparison.

1318. Differential gearing for spinning machinery. Presented by Messrs. Dobson & Barlow, 1896. M. 2930.

This is an example of a modern arrangement of gearing for correcting the motion of the bobbins in textile machinery, so as to neutralise the effect of the growing diameter of the bobbin as it fills.

In this construction the main driving power is received by the central shaft, to which in the model a hand wheel is attached. This shaft moves with the fliers, and also carries a reversed-cone arrangement, through which some motion can be transmitted to the central sleeve. The large spur wheel at the end drives the bobbins, and its motion is a combination of that received from the central shaft and that from the central sleeve.

On the driving shaft is secured a bevel wheel of 32 teeth, and on the sleeve that drives the bobbins one of 36 teeth. Between these two wheels is a spherical surface supporting a double-face bevel wheel, with 36 teeth on each face. The edge of this wheel extends outward as a flange which rests against a cam or swash-plate connected with the central sleeve. As the swash-plate revolves it rocks the ring on the spherical centre, causing it to gear with the two facing bevel wheels, so giving a mechanical ratio of 36 : 32. If the central sleeve is stationary, the bobbin wheel revolves at $\cdot\dot{8}$ of the speed of the driving axle, while if the sleeve also revolves it adds $\cdot\dot{1}$ of its speed to that of the driver; if it revolves in the reverse direction it deducts this amount. By a belt moved along the reversed-cone pulleys the amount of adjusting motion introduced through the central sleeve is accurately controlled.

1319. Bobbins for cotton spinning. Lent by Messrs. Wilson Bros., 1894. M. 2726.

During the later stages of cotton manufacture the material undergoes its treatment while passing from one bobbin to another, and the consequence is that the number and variety of bobbins required is very great, while their wear and tear is such as to necessitate considerable strength in their design and construction.

These several specimens are arranged in the order of the processes in which they are employed, and in many cases full and empty bobbins are shown, together with sectional drawings.

No. 1 is a slubbing tube, and is the first and largest bobbin employed in cotton manufacture. It is of beech with the ends strengthened by metal tires, beaded on and provided with notches for driving.

Nos. 2–4 are similar tubes but smaller, and are in use successively while the drawing and twisting of the yarn is being gradually advanced.

No. 5 shows the smaller and single-ended bobbins used while reducing the roving by ring spinning, by which process most of the final drawing and twisting is performed. Some of these bobbins are enamelled to enable them to resist the moisture or steam sometimes employed while spinning.

No. 6 shows the bobbin used when "doubling" in a ring frame.

No. 7 is used for winding "twist" or warp.

Nos. 8 are pirns, or bobbins, which when filled can be placed in a shuttle; in the adjacent shuttle a pirn is shown in position.

1320. Model of self-acting mule. (Scale 1: 4.) Woodcroft Bequest, 1903. Plate VI., No. 3. M. 1775.

This is a model of a mule for cotton spinning, patented in 1839 by Mr. James Smith, of Deanston. The machine was a rival of Roberts's self-acting mule, and this model was made when Smith unsuccessfully attempted to obtain an extension of his patent.

The driving wheels and pulleys, together with the mechanisms by which the various operations are performed, are contained in the head-stock, which is arranged parallel to the "race road." Upon this track a carriage holding the spindles traverses backwards and forwards, and while so doing draws and twists the yarn. At one end of the track is the beam, a transverse fixed frame holding the creels in which the bobbins are placed, and also the rollers through which the rovings from the bobbins are delivered for spinning.

When the carriage is in near the beam, the rollers are set going and the spindles rotated rapidly, the yarn leading off the end of each spindle being thereby twisted; the carriage meanwhile moves outwards slowly, gaining slightly upon the rollers and so extending the yarn, and when it has reached the end of the stretch it is stopped. The spindles, however, still continue to rotate and further twist the yarn, the carriage moving very slightly backward to keep the tension constant, as the twisting of the yarn shortens the threads. When enough twist has been put into the yarn the spindles are stopped, and a stripper moves up and takes off the few coils of yarn round the end of each spindle. The carriage now begins to move quickly back to wind in the finished yarn, and the upper faller wire comes down and guides the yarn to the spindle, so that it shall be wound into a cop by the superposition of conical layers upon the cop-bottom, formed at first by special movements of the faller wire.

The running in and out of the carriage is performed by a long rack attached to it, and supported in guides on the headstock. This rack is driven by a spur-wheel on the headstock, and the reversal of the motion is obtained by a mangle-wheel gear. A pair of large spiral wheels introduced in the train gives the variation of velocity necessary for quickly starting and stopping the carriage, while the slight motion of the carriage inward required when the extended yarn is being finally twisted is obtained from the motion of the mangle pinion when moving radially from external to internal gear. The difference between the diameters of the internal and external gears gives the much higher speed required by the carriage when winding in, compared with that while drawing.

The whole of the spindle and carriage motions are derived from two crossed belts, running uniformly, but each shifted during the cycle. The upper belt drives the carriage and rollers, and also the spindles during the winding in, but the power to the spindles is transmitted through a three-spur-wheel differential gear. One of these wheels has a **V** rim,

in which rests a brake rope under constant tension, and when the power transmitted exceeds this tension the wheel slips round idly, and the speed of the spindles is reduced by this lost motion. In this way the variable velocity required by the spindles while winding on is obtained, the gear slipping when the tension on the yarn rises above the normal amount, through attempting to wind on faster than the motion of the carriage allows.

The lower belt runs at a higher speed, and when on its fast pulley drives the spindles while the twist is being put into the yarn. The spindles are rotated by quarter-twist belts, from a drum extending the whole width of the carriage, and driven by an endless rope that passes round pulleys at the extremities of the headstock. The cop-builder receives its motion, partly from a travelling wheel of the carriage, and partly from a roller that comes in contact with an incline fixed to the floor. The feed rollers are driven from the headstock by a claw clutch, which, by a lever worked by a cam, is only in gear while the carriage is running out.

In modern mules the mechanism employed differs considerably from that in this model, and the front rollers are always arranged as drawing rollers.

1321. Model of mule headstock. (Scale 1 : 4.) Presented by H. Brierly, Esq., 1871. M. 1224.

This is a model of a headstock in which several of the mechanisms patented by Mr. James Potter in 1836 are introduced. The general mode of action of the mule, to which this headstock belongs, is similar to that of other spinning mules, and as described in the adjacent model of a complete mule, No. 1320.

The distinctive features of this headstock are: the vertical arrangement, with the intention of saving floor space; the use of a "spiral drum and hyperbolic screw" for regulating the speed of the spindles while winding on; the employment of a revolving crank motion for taking in the carriage, and the use of a sector rack with a varying stop, for effecting the operation of backing off. The model is not complete, but shows the leading peculiarities of Mr. Potter's arrangements.

The varying velocity of rotation required by the spindles, while winding on and building up the cop, is obtained from a conical spiral drum, made of sheet metal. Within it was to have been a nut, which could be screwed along axially, and that carried one end of the chain which, after passing round the drum, is connected with the spindle driving gear by the usual endless rope. The drum is driven uniformly by bevel gearing during the winding-in of the carriage; and when forming the cop-bottom the drum chain is at the large end of the drum, so receiving its maximum motion with a moderate variation in velocity but, as the spindles fill, the drum chain is slowly advanced towards the other end of the drum, where the mean speed is less and the variations greater; when the end is reached the nut ceases to travel, so that the cop, after this, is completed in a series of similar conical layers. The winding-on gear is driven through a clutch at the top of the headstock, and when this clutch is released the chain is unwound from the drum by a weight ready for the next winding on.

For the backing-off motion this clutch is put into gear with a sector rack and cam, the varying amount of backing-off required while building the cop being provided for by a vertical rod raised by a cam, so as to limit the motion of the rack. The motion of the carriage is given by a band on the pulley on the lowest shaft, which is reversed for the in-and-out movements. When the carriage is running in, this shaft is driven by a chain attached to an overhanging crank arm, which is slotted concentrically and rotated by a stud playing in the slot. When the crank has reached its highest position, its weight causes it to swing

round in advance of the stud, so leaving the carriage free to commence its outward motion, which is obtained from gearing connected with the drawing rollers.

1322. Cotton-ball winding machine. Presented by Lady Hawes, 1858. M. 350.

This is a small example of the machine invented in 1802 by Sir M. I. Brunel for winding cotton thread into balls. Cotton and flax thread at that time were sold in skeins, but the convenience of the balls turned out by this machine had an important influence in increasing the demand for cotton sewing thread. The first of these winders was used at Mr. Strutt's mills at Belper.

The model consists of a flier on a horizontal axis through the centre of which the cotton is introduced. The motion of the flier winds the cotton round a revolving spindle set at an angle, a coil being put on the spindle at each revolution, but the position of the coil or ring changes with each turn. The angle at which the spindle is set can be altered by hand and in this way the shape of the ball produced can be greatly modified. Universal joints and a sliding hollow shaft communicate a slow motion from worm gearing to the inclined spindle, and a band from a grooved pulley gives a high speed to the flier.

1323. Winding or spooling frame. Presented by Messrs. Robert Broadbent & Son, 1901. M. 3199.

This is a short length only of the machine used for winding yarn from cops into large spools, of either cylindrical or conical shape, ready for use in doubling or in knitting machines. The example represented embodies several inventions patented by Mr. R. Broadbent between 1886–93, and is usually arranged for winding 20 cylindrical spools along one side, and 20 conical ones along the other, with the driving pulley at one end and the special mechanism at mid length, as shown in the attached photographs of a complete frame. If the spools are being prepared for treatment in a doubling frame the yarn from several cops is simultaneously being wound on a spool, but if for knitting the yarn is wound singly.

The cops are placed on vertical skewers in front of the machine, and the yarn from them passes through wire eyes and over an angularly adjustable blanket-covered rail, by which the winding tension can be controlled; it then passes through detector wires, by which the winding of the spool is stopped should any of its yarn break, and is wound on its spool at a constant peripheral speed owing to the spool resting on a revolving drum which drives it by contact. In the conical winder the driving surface is conical, as is also the central core of the spool.

As the spools are formed on cores without flanges, the requisite cohesion is obtained by winding the yarn in reversed helices of large pitch, obtained by the motion of a traverse bar driven by a crank whose arm is varied by the action of a fixed pointed-oval groove or cam which gives uniform winding and a rapid reversal at each end of its travel. The winding drums or cones are driven by ropes from a continuous central shaft, while the detector wires are so arranged that should any yarn break its wire drops and comes into contact with a revolving wiper, by which the corresponding spool is lifted off its drum and its motion promptly arrested by a stop on its centre.

1324. Heckles for flax. Presented by C. E. Cowper, Esq., 1897. M. 2978.

The first process in obtaining a linen yarn from the flax plant consists in soaking the stalks in water for about three weeks to dissolve the adhering material that binds the long fibres together. After drying, the stalks are passed between fluted rolls which crimp them and so loosen the contained

pithy matter; they are then hung vertically and beaten with a wooden blade till the waste material is removed.

The prepared flax is now ready for the heckling process, by which the long fibres are separated and straightened, while the coarse ones are split so as to secure greater uniformity, and the short fibres and some impurities, constituting together about one-half of the total quantity, are removed.

Heckling by hand is performed by taking a bunch of prepared flax and whipping it down upon the upstanding teeth of a fixed comb, drawing it through them repeatedly, and then reversing the bunch or strick, so as to treat the other end.

The heckles shown are of French make, and are to be secured on a horizontal bench, when the teeth will slope away from the operator at an angle of 70 deg. with the horizontal. There are 32 long tapered teeth in each of the three rows, the length giving great flexibility, and they are secured in two stout plates of horn which also prevent the wooden base from splitting. At the back of the bench is a sloping board (not shown) by which the flax is confined to the upper extremities of the teeth.

The long flax, or line, is by this treatment left in a fit state for hand spinning, while the short fibres removed are afterwards worked up into an inferior linen yarn.

1325. Yarn testing machine. Lent by Messrs. Cook & Co., 1905. M. 3408.

This is a machine, patented in 1902 by Mr. J. B. Moscrop, for automatically testing and recording the strength and regularity of yarn or thread. Successive lengths of the material are taken, held by grips at each end, and stretched until they break, the breaking strength being recorded by needle pricks on a strip of paper. This method is superior to that in which a number of turns of yarn are tested at once, because in that case the average result may differ from the actual strength.

The machine consists of a framework having at one end a row of horizontal grips attached by springs for measuring the tension. Opposite to these is a carriage, having a similar set of grips, and the cops of yarn to be tested; this moves inward to carry the yarn to the fixed grips and then runs back to stretch it. The carriage is traversed by the upper end of a slotted lever pivoted at its lower end, and the slot engages with a crank pin fixed to a shaft driven by spur gearing from a belt shaft supported on the frame. This gives a quicker motion to the carriage on the inward stroke.

On the same crank shaft is a cam which raises one end of a weighted lever, the other end of which actuates the fixed grips and pricking mechanism. The fixed grips each consist of a pair of jaws pressed together by plate springs, and opened by the partial rotation of a flattened pin passing through a slot between them. The lower end of the pin carries a crosspiece having turned-up ends with inclined top edges; above the jaws is fixed a flat spring having at its free end corresponding inclines, which, when depressed by studs fixed to a cross bar pulled down by the cam lever, turn the pins and spread the jaws. The grips are each mounted on a long slotted plate resting on antifriction rollers, and are attached by adjustable helical springs to the end of the main frame. Above the grips is mounted a frame pivoted at the rear end, and held up by springs; this carries a pair of bars over each grip-plate, along which slide carriers holding vertical needles. When the yarns are pulled the needles are moved forward by the grips, but when they break the grips fly back, leaving the needles behind. The needle frame is depressed by the same bar that opens the grips, by means of bell crank levers, which after moving a certain distance are released through their free ends coming into contact with stops, thus causing the needles to rise rapidly while the bar goes on descending. After the records are made, the needles are returned to their normal position by a bar, which is moved back by the carriage, and restored by springs. Below the needles a padded table is arranged, upon which the recording paper is

clamped; this is moved transversely after each test by a screw rotated by a ratchet, which is moved by the carriage when it reaches the end of its inward stroke. The table, at the end of its traverse, throws out a clutch on the driving pulley and stops the machine. When the grips are open to receive the new lengths of yarn, strippers pass between them to remove the broken ends, which fall into a tray below; these are also actuated by a lever and spring bar moved by the carriage. The travelling carriage runs on four flanged wheels along the top edges of the frame which partly incline downward toward the fixed grips. At the front of it, a corresponding number of grips are arranged, similar to the fixed ones, but with their jaws placed vertically. The spreading of the jaws is performed by oval pins, to which are attached arms projecting downward from behind; the arms engage with notches in a cross bar, which slides transversely through holes in the carriage sides, and is pushed from side to side by its projecting ends coming into contact with fixed stops. A notch in the bar engages with the frame and prevents it from springing back, or the jaws from closing, until the carriage reaches the closing stop. The cops are arranged on horizontal spindles at the back of the carriage, and the yarn passes round wire guides before reaching the grips. In order that the yarn may be placed in the fixed grips, the end portion of it is raised to a vertical position by a notched and perforated plate attached to the carriage normally lying flat under the yarn, but raised up at the end of the inward stroke by levers attached to it. The inclination of the rails lowers the carriage, and allows the orifices in the plate to pass over the fixed grips, and thus carry the yarn between their jaws.

The sequence of operations is repeated until the necessary number of 12 in. lengths of yarn have been tested, the successive tests being recorded side by side on the paper, and forming a diagram showing the strength and regularity of the yarn. The paper shown is arranged for 80 tests, after which the machine is automatically stopped.

WOOLLEN MANUFACTURE.

Wool is a fibrous growth of the nature of hair, but differing from it considerably in its structure. Each fibre is about ·001 in. diam., and is covered with minute scales which overlap one another like those of a fir cone. There are sometimes nearly 3,000 of these rings to the inch. It is due to the roughness caused by the scales, assisted by the curled form that the fibres assume when heated, that woollen materials can be made to give so close a texture, as in milled and felted goods. The working of wool into a textile fabric has for centuries been one of the staple industries of this country, but until within comparatively recent years the wool was washed, combed, and spun by hand and then woven into cloth on a hand loom. With the exception of the original shearing and the sorting processes, all of the manufacturing is now done by machinery, and the processes followed in many respects resemble those of the cotton industry. A series of labelled specimens (*see* No. 1326) shows the wool during various stages in its manufacture, and will assist in explaining the action of the successive machines, some of which are not at present represented.

Raw Grease Wool.—This is the term applied to the wool as it is taken from the sheep. Such wool differs greatly, even in the same fleece, and it is consequently sorted and classified by hand, according to its fineness. Most wool is white, the dirty colour of grease wool being due to impurities, chiefly greasy matter secreted by the skin and dirt that this accumulates, the impurities making about one-half of the weight of the grease wool.

Scouring.—Some of the dirt is frequently removed by passing the wool through a form of "devil" that knocks the material about, so loosening the dust, which then escapes through the netted sides of the machine. Where the sheep are washed before being shorn, the wool is cleaner, and is at once scoured, this being the general practice. Scouring is a gentle washing in hot alkaline water, which removes the grease and dust; the former is afterwards extracted from the soapy solution by sulphuric acid. The scouring is performed in long hot-water tanks, or bowls, with double bottoms, the upper one being perforated so that the dirt may pass through it and settle. The wool is dragged through the water by mechanically moved forks, which at the delivery end lift the wool on to an apron, where a squeezing roller expels much of the water. The wool then falls into a similar tank for a final scouring in cleaner water. It is then conveyed to a heated drying chamber, through which it slowly travels, at the same time being exposed to a draught of hot air propelled by a fan.

The wool having now lost its natural grease is harsh, and the fibres do not adhere, so before further working it is usually found necessary to add oil. About two gallons of olive oil are used for 120 lbs. of wool, the oil being sprayed on by a revolving brush as the wool travels along on a feed sheet.

The different kinds of wool are now blended, and thoroughly mixed and disintegrated by being passed through a machine called a fearnought that somewhat resembles a carding engine. It has a large cylinder revolving quickly, and three pairs of small rollers working close to it. Each of the cylinders is covered with teeth, and the wool, which is carried on by a travelling apron, is taken in by a small feed roller, passed through the series of workers and strippers, and is then drawn off by a fan.

Carding.—This process, when employed in the preparation of wool, is usually performed in a series of three carding engines, called respectively the scribbler, intermediate, and carder, the reason being that the carding process has to deliver the material as sliver ready for spinning, without combing or drawing. After carding, the breaking up of the lap is performed by a condenser, which is a machine with card-covered cylinders with the card clothing arranged in rings, leaving spaces between equal to the width of the rings.

The ribbons which these rings strip from the doffers pass through a pair of rubbers, which press or round them into slivers ready for the mule frame.

Wool is, however, worked into two entirely different yarns, known as worsted yarn and woollen yarn. In worsted yarn the fibres are all long, and are arranged nearly parallel, so giving the material a smooth surface. In woollen yarn the fibres are of various lengths, and lie in all directions with many loose ends projecting, so giving the yarn a rough surface. This irregular surface of the woollen yarn is of great importance, as cloth woven from it will, when felted or milled, present a smooth and even surface, concealing the individual threads, owing to the interlacing of the adjacent fibres during the milling process. This three-stage carding and condensing practice is followed in preparing woollen yarn, everything being done to prevent drawing or any parallel arrangement of the fibres.

For worsted yarns carding is not much used, as the long fibres may be broken by the cards. A better result is obtained by cleaning and separating the fibres in screw gill boxes. This process, known as "preparing," consists in feeding the wool by rollers into one end of a gill-box and drawing it out at about three times the speed by rollers at the other end, the wool between the two rollers being gently combed by spiked rods that travel at an intermediate speed. These rods are called fallers, and are driven by endless screws. On reaching the end of the travel, each faller drops down upon similar but reversed screws that return it. Five or six of these gill-boxes are used in preparing, the wool passing through the first three as a lap and through the others as sliver, six slivers being united or doubled by each of the succeeding boxes so as to secure uniformity as well as gradual straightening.

Combing.—Just as in cotton manufacture, the object of this operation is the removal of the short fibres from the carded lap. The three machines most common are the Lister, or nip, the Noble, or circular, and the Holden, or square-motion machine. They all act by pulling the wool through teeth, but without separating it, and then delivering it as sliver for winding into rolls or upon bobbins for drawing. The noils, or short wool, are at the same time being continuously cleaned from the teeth and deposited in cans.

Drawing.—In order to prepare fine roving for the spinning frame the sliver from the combing machines is successively drawn by rollers in six or nine different drawing frames. Six ribbons would be combined in the first machine, six in the second, five in the third, four in the fourth, four in the fifth, and two in the roving frame. In all the wool is thus doubled 5,760 times. In each machine there are two pairs of rollers,

of which the front pair revolves more quickly than the back pair, and thus a drawing action goes on, the sliver getting thinner as it goes from one machine to the next. There are two kinds of drawing machines used in England, which differ chiefly in the method of controlling the motion of the bobbin. The open drawing machine gives no positive motion to the bobbin, but the thread pulls it round against the frictional resistance of a disc of leather placed between the lifting rail and the lower flange of the bobbin. In the cone drawing machine the bobbin is driven through a pair of conical drums, which adapt the speed to the varying diameter of the bobbin. The wool from the last drawing box is called slubbing (*see* No. 1326).

Roving.—This process is a continuation of the preceding drawing process but in winding in, a twist of about one turn per inch is given, and the yarns from two bobbins from the last drawing box are drawn and twisted into a single roving.

Spinning. — Worsted yarn, which has been through the process known as French drawing, in which no twist is put in, is spun finally in the mule frame, a cop being formed by winding the yarn on the spindle. Other methods of spinning are by the bobbin and flier, the cap, and the ring frame. The first of these is the ordinary throstle frame; it is used for spinning thick and medium worsted yarns, the spindles being run at 3,000 revs. per min. The cap frame contains fixed spindles, a cap outside each bobbin resting on the spindle, and a tube inside each bobbin which turns with the bobbin. This frame can be run at about twice the speed of the throstle and is suitable for spinning fine worsted yarns. The ring frame is similar to that which is used for cotton spinning. It produces the same kind of yarn as the throstle, which it is fast superseding, as in cotton spinning. Cops of yarn for weft and warp on the paper tubes on which they have been spun, and samples of double yarn are shown. They have been formed by the combination of two or more threads of yarn in a ring or throstle frame.

Wool which has been scoured is usually white, and the whiter it is the better, but some kinds of East Indian, Egyptian, and Spanish wool are coloured grey or brown naturally. The natural colours of yarns obtained by careful selection are permanent.

1326. Specimens of wool, showing stages in the manufacture. Presented by Messrs. W. Holland & Sons, 1890. M. 2318.

These commence with wool as taken from the sheep, and show the material after it has undergone each of the successive operations of scouring, carding, combing, drawing, and spinning. The shades obtainable by blending the various colours of natural undyed wool are also indicated.

1327. Model of Heilmann's wool-combing machine. Contributed by J. Wilson, Esq., 1860. Plate VI., No. 5. M. 738.

This represents the combing machine invented by Josué Heilmann, of Mülhausen, for use in combing wool, cotton, or other fibrous substances, and patented by him in this country in 1846. The complete combing machine by Messrs. Dobson & Barlow, No. 1305, is a development of Heilmann's invention, but constructed for treating cotton, while this model is arranged for combing material with a longer fibre, and was made to illustrate the patent specification.

The wool is fed in through a slot and passes first between the teeth of two fixed combs, and then between two blades which form a pair of nippers. The blades are fixed to levers moved on fixed centres by cams on the main shaft, so that at the proper time the nippers move down towards the main cylinder, upon which are rows of needle points forming combs. These combs take out the short fibres and foreign matter, while the nippers hold the long fibres; the cylinder turning continuously. After the combs on the cylinder follows a portion which is fluted, the nippers then open and a single comb below them is moved so that its teeth enter the wool from below, and carry it forward towards two rollers which are mounted upon an arm operated by a third cam. The upper roller is covered with leather and the lower one is fluted; the former, which is turned by contact with the fluted portion of the cylinder, takes up the long fibres which have been pushed along towards it; the lower roller at this time is not in contact with the cylinder. Then a part of the cylinder which is covered with leather comes round, and the lower roller is moved by the arm to which it is attached into contact with the cylinder, and, being in contact with the top roller also, turns the latter back a little way, and with it the fibres. The combs now coming round again, comb the other ends of the fibres, and when the next nip of wool is brought on by the reciprocating comb, the ends are laid over the ends of the former nip, which project from between the rollers, and a continuous sliver or sheet is formed.

The combs are cleared of short fibres by a bar between each pair; they fall on the surface of a roller which is not represented in the model. One of the rollers is turned by gearing and the other by friction, and their motion is reversed at each nip for the purpose of allowing the short fibres last taken out to be joined on to the preceding ones so as to deliver the combed waste wool as a continuous sheet.

1328. Model of Heilmann's wool-combing machine. Contributed by J. Wilson, Esq., 1860. M. 738A.

This is an incomplete model of Heilmann's combing machine. It is intended to represent the same machine as No. 1327 with a different arrangement for feeding the wool. It shows the combing drum and the detaching rollers.

1329. Model of wool-combing machine. Contributed by J. Wilson, Esq., 1860. M. 735A.

This is a sectional model of part of a machine for combing wool, patented by Messrs. Donisthorpe and Whitehead in 1849.

Before reaching this portion of the machine the material has been fed along by a travelling apron, pressed between two pairs of rollers, and carried forward at 50 or 60 times the speed of the first apron on a second apron, the one shown in the model. The wool now passes out between two brushes, and is taken hold of by a comb which projects through a gap in a rotating cylinder. On the cylinder there are four such combs, each fixed to the end of an arm centred at the other end on the boss of the rotating cylinder and having at its middle a roller which runs in a cam groove cut in a fixed plate. Four other combs are fixed to the outside of the cylinder, working in pairs

with the first four. As a pair of combs comes round to a point opposite to the delivery rollers, the arm comb is leading and standing out from the cylinder, but the shape of the cam now makes it travel slower than the cylinder and allows it to take the wool gently from between the brushes. The comb fixed on the cylinder then overtakes it, combs the wool out, and carries it round to the opposite side. Here there is a travelling band, carrying combs that pass near enough to the cylinder for the combs on the band to loosen the wool in the teeth of the former comb. The band and the cylinder are moving in the same direction at this point, and the two combs hold the wool jointly and place it upon the teeth of a circular comb. A brush follows the cylinder comb, and, under the action of a cam plate, presses the fibres well into the teeth of the circular comb, which is revolving, and so carries the fibres round till they are seized by a pair of fluted rollers which draw them off and deliver the combed wool as a sliver. Each of the four combs acts in this way so as to give a continuous output. The arrangement for removing the short fibres from the combs is not shown in the model.

1330. Model of portion of a "Lister" wool-combing machine. Contributed by J. Wilson, Esq., 1860. M. 733A.

This shows the arrangement, patented by Messrs. Lister and Donisthorpe in 1850, for holding or nipping the ends of woollen fibres while combing.

Before arriving at this part of the combing machine the wool has been fed in on a travelling apron, passed between fluted rollers and through a box of screw gills. The gills are combs that travel from end to end of a box, and draw out the fibres and straighten them by the action of their teeth. The nipping arrangement then takes hold of some of the fibres and carries them over till they are taken up by a revolving brush and transferred to combs on the edge of a large circular plate. By these combs the long fibres are taken hold of as the plate moves round, and further on the noils, or short fibres, are taken out.

The model shows a fluted cylinder with two blades, each of which is made to project as it comes to the endless band. To assist in taking hold of the fibres, a guide plate, fixed to the end of an arm centred below, is moved slightly beneath the band by an eccentric from the main driving axis, but this is not shown in the model.

1331. Model of wool-combing machine. Contributed by J. Wilson, Esq., 1866. M. 1015.

This represents the combing machine patented in 1859 by Mr. C. Whipple, of Providence, U.S.A.

The lap of wool is fed in at one end of the machine on an endless apron of leather. It then passes through a box of screw gills placed over a chest heated by steam, the heat softening the wool and assisting the action of the gills or combs. At the end of the gills there is an upper vertically-sliding blade, and a lower fixed one, which act together as nippers. When a certain length of lap has been fed on, the upper blade is moved downward and holds the ends of the fibres. The small combing cylinder, which is mounted on swinging brackets, is then moved up from below; it turns and combs out the short fibres and then is moved down again. The combs of the screw gills and the screen combs in front of the nipper blades now move up and pass their teeth through the lap of wool. The movable blade is then raised and a second pair of nippers slide towards the first pair, take hold of the ends of long fibres, and then, moving back, they lay the fibres on the travelling sheet, which is covered with teeth. The combed wool is thus passed to the delivery rollers and out through a guiding funnel.

The short fibres, called noils, are collected from the revolving comb, when in its lowest position, by a revolving brush which in turn is cleared by a cylinder set with long teeth. From this the short fibres are removed by a comb which delivers them in the form of a lap or sheet. The nippers and teeth are also cleaned by brushes.

SILK MANUFACTURE.

Silk is a fibrous substance produced by the larvæ of many insects as a protective covering during the chrysalis stage, and in structure somewhat resembles the web of a spider. The silk fibre used in manufacture is, however, almost exclusively derived from the mulberry silk-moth (*Bombyx mori*). When the larva is fully mature it forms its cocoon by ejecting from a pair of glands in its head two filaments, each about 1,400 yards long, which stick together and form a single thread of two strands, but without twist. The diameter of the fibre is from ·0005 in. to ·001 in., and its breaking strength is equivalent to over 20 tons per sq. in. Owing to the form and properties of this fibre the manufacture of silk is free from the complications seen in the preparation of cotton or wool.

Reeling.—When the caterpillar has completed its cocoon, which is learnt by rattling it, the larva is killed by heating to 70 to 90 deg. C., and the cocoons are placed in warm water to soften the gummy material. After removing the external flossy silk, the filaments from four or five cocoons are unwound and reeled up together into hanks, in which state the material is known as raw silk. The reeling appliances used are seen in No. 1332.

Throwing.—This is a general term used to include the various processes of winding, twisting, doubling, and retwisting raw silk, by which a uniform thread of greater strength and bulk is obtained. The raw silk is dipped into warm water to soften the adhering gum, wound on skeleton reels, or swifts, and then upon bobbins by revolving fliers which give some twist, but very little, as twisting reduces the brilliancy and softness of the material. The finished thread is dyed and afterwards woven in power looms.

Spun Silk.—Floss silk, damaged cocoons, and similar materials were for many years treated as waste, but in 1857 Mr. S. C. Lister, of Manningham (Lord Masham), discovered a method of converting it into thread by a series of processes resembling those employed in cotton manufacture. This material is known as spun silk, and its production has become a most important industry.

1332. Silk-reeling machine. Received through Sir Thomas Wardle, 1882. M. 1788.

This is a complete machine of the type most generally used in the south of France and Italy.

The cocoons after sorting are placed for a few minutes in boiling water in order to remove the outer covering and to find the end of the filament. They are then transferred to the basin in the large tray, containing water that is maintained at temperature of 85 to 90 deg. C. by a steam pipe or a small stove. The ends of the filaments are collected to the hook in front of the tray, and detached in two threads of four or five filaments at a time. Each thread is passed through an agate or procelain draw-plate in an arm attached to a standard fixed beside the basin. The two threads are crossed or twisted for the purpose of rounding them, and are then led by glass hooks to a reciprocating guide, by which they are distributed over the face of the reel. The reel is driven by hand through friction gearing, and has a friction brake for stopping it.

1333. Models of portions of silk machinery. (Scale 1 : 2.) Transferred from the Tower of London, 1857. M. 351.

These are the remains of the three models deposited in the Tower of London in 1741. Sir Thomas Lombe had introduced certain silk-working machinery into this country from Italy, and in 1718 had patented three of these machines, one to wind raw silk, another to spin it, and the third for twisting organzine silk. In 1719, he established a silk mill at Derby. In 1732 Parliament granted him 14,000*l.* in lieu of an extension of his patent, but required that models of his machines should be deposited for public reference. The portions shown are a reel, three spindles with bobbins and fliers, and a segment of a circular frame, but particulars have been preserved that make clear the construction of the throwing machine to which it evidently belonged.

Each spindle has a bobbin secured to it, and at its top runs loosely a double-ended flier by which the silk is led from the bobbin and delivered, with a certain amount of twist, to a reel or swift that was supported above. The spindles were arranged vertically, in 16 sets of six, forming a complete circle, and they were driven by frictional contact from a central driving wheel. The silk from each set of six bobbins was wound on to one swift; the swifts were driven by reducing gearing from the main shaft. and the whole mill was driven by water power. The model was half size with a bobbin circle 6 ft. diam., the usual size being about 12 ft.

A drawing (scale 1 : 16) is attached showing plans and elevations of the silk-throwing machine as it would have appeared. A drawing of a hand-power throwing-mill also shows that the general arrangement of this early machine is still followed.

1334. Model of silk-throwing machine. Contributed by the Commissioners for the Exhibition of 1851. M. 651.

This is a model of a portion of a machine for winding silk upon bobbins. On the vertical spindle runs a sleeve that carries a bobbin, and from the top of the spindle two flier arms, by which the silk threads are led on to the bobbin, extend downward. The bobbin and flier are driven independently by skew bevel gear, so that in winding on any desired amount of twist may be put into the thread. A modified form of spindle is also shown in which the bobbin is driven by a band pulley. A small cistern provided with wire guides is arranged above the model, so that probably this machine was intended to wind directly from cocoons on to bobbins.

1335. Silk-throwing machine. Presented by Thomas Dickins, Esq., 1873. Plate VI., No. 2. M. 1763.

This machine has a vertical spindle which is driven by bevel friction wheels below and has on it a frame carrying two bobbins. On these have

been wound the two threads that are to be twisted together, and the machine does the twisting while the threads are being unwound from the bobbins and wound together upon the single reel above. The frame rests upon a shoulder on the spindle, and revolves with it by friction. To stop the machine instantly, should either thread break, an automatic arrangement is fitted. The thread from each bobbin is drawn through an eye in a wire whose other end projects a little through a hole in the base of the revolving frame; should a thread break, the wire which it supported drops further through the frame, and so in revolving strikes an arm which is fixed to a loose collar on the spindle. The arm has on it two rollers which, being forced up fixed inclines, lift the collar, which thus comes in contact with the bobbin carrier and arrests its motion; the winding reel above is driven by gearing from the bobbin, so that the winding also ceases.

WEAVING MACHINERY.

The art of forming a cloth by interlacing fibrous threads was evidently in use long before spinning was attempted as a means for obtaining suitable threads from such natural materials as cotton or flax. Grasses or straw and shreds of the inner bark of trees were used for both systems of threads, and were worked into mats by a process similar to darning. In very early times, however, yarns were spun from cotton and flax, but "fine linen" usually consisted chiefly of cotton, very finely spun.

The first step from this primitive darning towards the modern process of weaving seems to have been made by the ancient Egyptians, who arranged a series of vertical threads representing our present warps, and provided the alternate threads with a loop attached to a rod that served as a heald-shaft, by which one-half of the warps could be deflected from the common plane, so leaving a wedge-shape space, or shed, for the passage of the cross thread, or weft. By a similar heald-shaft the other warps were deflected for the return passage of the weft, and so the interlacing was obtained in a much more rapid manner than was possible by a darning system. Subsequently the ancient Egyptian, Greeks, and Romans used an elementary form of loom, in which the warp threads were suspended vertically from a beam and weighted below. Two lease rods were passed through the warp to separate the odd threads from the even. The weft was wound on a reel serving as a shuttle, which was passed through, or thrown, by hand, and a flat wooden sword, afterwards introduced in the shed, was used for beating up or pushing the weft thread home. A comb was employed about this time for keeping the warp threads apart, and soon afterwards was used instead of the sword for beating up the weft.

An early Indian loom had the warp placed horizontally, and worked by two healds suspended from above and connected with treadles below. To keep the cloth out to the proper width a temple was used; it consisted of two wooden bars tied

together with cords, and having at their ends brass pins to hold the cloth. Such primitive looms are still in daily use in the East.

From these early times, until early in the 18th century, very little improvement was made in the hand loom, the construction of which was such that the warp was rolled on a beam, round the ends of which ropes suspending a weight were coiled, and so kept the threads stretched. There were two healds worked by treadles below, and the beating-up was done by a batten swung from above. The upper surface of the batten, or lay, together with the reed, formed the shuttle race, and the shuttle was thrown by one hand and caught by the other at the other side of the shed.

In 1733 John Kay, of Bury, invented the fly-shuttle, by which the speed of weaving was immensely increased, and the labour diminished. His shuttle was made of light material, and ran upon four wheels. Pickers at each end of the web were connected with a stick which the weaver held in his right hand, so that by a quick movement of the wrist either way, the shuttle ran through the shed, and was caught by the other picker, ready for the return passage. In 1760 Robert Kay, son of the inventor of the fly-shuttle, invented the drop box, an arrangement whereby several shuttles with different-coloured wefts could be used, instead of only one. It consisted of a vertical board at each end of the lay upon which several shelves were fixed. Each of these was designed to hold a shuttle, and was capable of being brought level with the picker when the weft of any particular shuttle was required in the pattern.

The method of picking remains essentially the same as it was in the 18th century. Many efforts have been made to improve it, but it is still uncertain in action, costly, and dangerous. Many multiple box-motions, beginning with Dr. Cartwright's sliding tray in 1792, have been introduced in order to weave fabrics with different colours of weft by automatically changing the shuttle. Swivel-weaving is a method of producing small figures in extra weft carried in swivel shuttles over the ordinary ground weft. It gives an embroidered appearance, and the extra weft is only used where the figures are made. Lappet weaving produces similar but somewhat inferior effects by means of floating warp threads.

Much attention has been recently directed towards devices for the automatic renewal of the weft supply. These are of two classes, one in which the shuttle is replaced by another fully charged, and the other in which the empty spool or cap is taken out of the shuttle and replaced by a full one; the former are the more numerous. The Northrop weft-changing mechanism, patented in America in 1894, has been the most successful. In 1907 120,000 looms were in operation, working on this principle. The cops of weft are placed on 28 skewers carried in a revolving hopper, when the weft supply is nearly

exhausted the skewer in the shuttle is ejected and a full one from the hopper automatically replaces it. The shuttle is self-threading.

In 1785 Dr. Edmund Cartwright took out his first patent for a loom that could be driven by water or other power. A year later he described means for automatically stopping such a loom should the warp or weft break; also the taking-up and letting-off motions, and mechanical motions suitable for driving the picking stick and the lay. In 1787 he provided a stop motion for arresting the loom should the shuttle not box, and added a self-acting temple; in 1788 and 1792 he described further details and completed his invention, which included all of the important features of the modern power loom, but in a crude and almost impracticable form.

Open and Closed Sheds.—In shedding, that is raising or depressing the warp threads to make a passage for the shuttle, there are two principal methods in use, the sheds being known as open and closed respectively. An open shed is formed when the warp threads pass directly from their highest to their lowest position, so that an open space is constantly preserved except during the instant when the warp threads are passing one another. There are two ways of producing a closed shed: in the first, the warp threads that are to lie above the weft are lifted up, and those that are to lie below the weft are drawn downward to make a passage for the shuttle; after each pick all the threads are brought back to the centre line. The other way is to keep a fixed line of warp below the centre line, and to lift all threads that are to lie above the weft up to a line above the centre line. Less strain is put upon the warp by the open than by the closed shedding, and the former occupies less time, but it is a difficult matter to piece broken warp threads in the lower shed. An open shed is the usual form, and is found in all ordinary tappet and dobby looms; a closed shed of the first kind is formed by single-lift Jacquards, and one of the second kind by the Woodcroft tappets and certain Jacquards.

Mechanisms for effecting the shedding operations are of three different kinds according to the complexity of the pattern. The simplest of all is the tappet motion, in which cams placed upon a shaft act upon treadles which are connected with the heald-shafts. Each heald has an eye through which a warp thread passes, and in general there are as many heald-shafts as there are weft threads in a repeat of the pattern, but by an arrangement known as drafting the number necessary for weaving some patterns may be reduced. Tappets cannot be used with advantage when the heald-shafts exceed 12, so that to produce the shedding motion for patterns beyond the scope of tappets a mechanism known as the dobby, or witch, is used. Even where the pattern is not so intricate as to be beyond the range of tappets, the dobby is often used on account of the greater facility with which it can be changed from one pattern to

another. The dobby appears to have originated separately and to have been earlier than the Jacquard machine; some kinds of dobby are very like the latter in their parts, but they are not suited for the most complicated patterns. In cotton weaving 24-shaft dobbies, and in worsted weaving 36-jack dobbies are used.

The Jacquard machine was invented partly by Falcon in 1728, partly by Vaucanson in 1745, and completed by Jacquard in 1804. Falcon invented the prism with its chain of cards, Vaucanson applied the griffe to lift the hooks, whilst Jacquard appears to have combined the previous inventions and made the machine a commercial success. Improvements in the details of the Jacquard of late years have been numerous, and they have aimed at increased speed and reduced cost of production. For cutting holes in the cards two classes of machines are used, those for cutting cards from a design on squared paper, and those used for repeating a set of cards. No machine has yet been successful in automatically reading the design on the cards. The piano card-cutting machine is the one most used for complicated designs. Since 1853 attempts have been made to control the lifting of the needles and hooks by electricity instead of by punched cards; experiments in this direction are still being carried on very actively.

For experimental weaving, as well as for many special fabrics, the hand loom is still in use on account of the ready way in which the changes can be made in the shedding or picking; for all weaving of industrial importance, however, the power loom is alone employed.

1336. Model of hand loom. (Scale 1 : 4.) Presented by the Society of Arts, 1857. Plate VI., No. 6. M. 40.

This model represents the general form of hand loom in use prior to the invention of the fly-shuttle in 1733; most of the features of the modern power loom are, however, to be found in it in an elementary form, and in a state that renders the action of the later developments more evident.

The longitudinal, or warp, threads are wrapped round a roller at the back of the loom frame, from which each one passes through an eye in a separate vertical thread, or heald, and then between a grid or comb, called a reed, to a roller in front, known as the cloth-beam, and upon which the fabric is wound up as it is woven. The healds of alternate warp threads are secured above and below to transverse bars, called heald-shafts, which can be moved vertically by treadles, and the healds of the intermediate warp threads are similarly controlled by another set of heald-shafts. By this means the alternate threads of the warp can be moved so as to leave a wedge-shaped space, called a shed, through which the shuttle, containing a supply of the transverse or weft thread, can be passed by hand. After each passage of the shuttle the healds are so moved as to reverse the relative positions of the two groups of warp threads, thus securing a complete interlacing of the two systems of thread; the weft thread is at the same time driven close up to the preceding thread by the reed, which is pulled forward to beat it up, or batten it.

The loom is represented weaving a stair carpet, with longitudinal stripes given by the use of warp threads of different colours; three threads are passed through each loop of the healds and the weft thread is quadruple. A full-sized shuttle is also shown.

1337. Model of velvet loom. (Scale 1 : 8.) Presented by Mrs. Reynolds, 1907. M. 3489.

Plush or pile fabrics have a raised surface, which is produced by the introduction of threads in addition to the ordinary warp and weft forming the ground or body of the fabric. They are of various classes, depending upon whether the pile is caused by additional warp or by additional weft threads and also upon whether the threads are cut or uncut.

The model represents a hand loom for weaving velvet, in which material the pile is produced by a great number of short silk warp threads, the ends of which stand up closely enough together to conceal completely the structure of the ground. The warp for the pile is carried upon an additional beam placed above the ordinary one, and separate heald-shafts are provided for its threads. In operation, the latter are raised and depressed together with one-half of the ordinary warp until three picks have been completed, when a brass wire is inserted below the pile warp and above the whole of the ordinary warp. The pile warp and half of the ordinary one are then depressed, three more picks are executed, another wire inserted, and the process repeated. In this way the pile threads are made to form loops around the wires, which loops are cut through by means of a special form of knife known as a trevette, each wire being provided with a groove along its upper side to facilitate this process. Two wires only are used, the loops round the one being cut after the other has been inserted. The intermediate picks are well beaten up by a reed so that when cut the pile threads are securely gripped by the weft. As many as 50 or 60 insertions of the wires are made per inch, and about six yards of pile warp are required for each yard of velvet produced. Smaller weights are employed on the pile warp beam than on the ordinary one, as less tension is required in the threads of the former.

The woven velvet passes to a cloth beam, but is not wound round it in the ordinary manner. To avoid crushing the pile, when the beam has completed nearly one revolution, the material is unfastened and passed through a slot near the top of the side of an adjacent box.

1338. Model of power loom. (Scale 1 : 3.) Made by Messrs. Sevill & Woolstenhulme, 1857. M. 1765.

This model represents an ordinary form of loom, such as is used for weaving calico, and it is arranged to be driven by power. The following description of the construction and arrangement of this simple loom applies generally to other models of looms in the collection.

The warp threads, or those that run lengthwise of the calico, are wrapped on a long roller placed at the back of the loom. Each thread passes separately from this roller through a loop in a separate vertical cord, known as a heald, and then forward in pairs through a grid or reed formed of vertical wires or dents, and finally on to a front roller called the cloth beam, upon which the woven calico is wound. The weft thread, or that which runs across the calico, is contained within a shuttle, which by a simple mechanism is thrown backward and forward along a ledge or shuttle race formed on the front of the reed. The interlacing of the weft and warp threads is due to the lifting and lowering of the alternate threads of the warp after each throw of the shuttle. The alternate healds are attached above and below to a frame or heald-shaft, and those intervening to a similar heald-shaft; but by means of cams below, these frames and healds are alternately lifted and depressed, so that the shuttle is passing at one throw above and at the next throw below each alternate warp thread. The wedge-shaped passage left for the shuttle between the lifted and depressed halves of the warp is

called the shed, and each passage of the shuttle is a pick. To secure close interlacing, so that the weft thread from one throw shall be as near as possible to the preceding, a swinging motion is given to the reed by which its dents push the weft right home into the vertex of the shed. The swinging frame carrying the reed is called a lay, and its beating-up motion is known as battening.

The motion of the shuttle is derived from a swinging arm or picking-stick, which passes through a picker made of buffalo hide, and is arranged in the boxes for the shuttle at each end of the shuttle race. The picking-stick is driven by a cam on the shaft, the return movement being given by springs. The lay is reciprocated by a pair of cranks and connecting rods. To move the heald-shafts up and down so as to form the shed, a tappet shaft is provided below, which makes one revolution for every two of the lay crank-shaft, and the tappets move treadles by which the motion is conveyed to the heald-shafts through leather belts. The warp is fed out as the work proceeds by a ratchet wheel, and the tension is regulated by a roller over which the warp passes. If too much warp has been fed out the roller rises and holds back the pawl by which the feeding is performed. The winding in of the finished cloth is accomplished by a similar gear.

There is an arrangement for stopping the loom if the shuttle does not reach its box after being picked; this consists of a lever held by a spring, and forming the outer side of a shuttle box. When the shuttle boxes, the lever is moved outward and a finger is raised; if the shuttle does not box properly the finger remains down, and, as the lay moves forward, catches a lever fixed to the stop rod, and the loom is stopped by the driving belt being thrown on to the loose pulley. Should the weft break, the loom is stopped by a fork and grid arrangement, described in connection with No. 1349.

The cloth is kept stretched to its proper width by a self-acting temple, which consists of a serrated roller cut with a right-hand screw thread for one-half, and a left-hand thread for the other half of its length. The cloth passes beneath this roller and over an iron trough in which the roller turns.

1339. Model of power loom. (Scale 1 : 2.) Woodcroft Bequest, 1903. M. 1778A.

This is a model of a loom fitted with Bennet Woodcroft's positive tappets, patented in 1838. This form of tappet is still used for heavy work, and where from 8 to 12 picks are needed for a pattern. The shed formed with these tappets is a closed centre shed, that is, the warp threads return to a common plane after every pick, and are then moved to their respective positions for the next pick.

There are four heald-shafts, each raised or lowered by the motion of a tappet plate, the projections upon which operate a lever or treadle. Each tappet-plate consists of two corresponding plates bolted together, and the plates are made in sections, which form either an elevator or a depressor. The sections may be interchanged so as to work different patterns by a different sequence of these cams. There are usually as many sections as heald-shafts, and the tappet-shaft makes one revolution for each section of the tappet-plate; in this example there are three sections, so the tappet-shaft makes one revolution for three of the crank-shaft.

Contrary to the present practice, the lay is supported by arms, or swords, from above, but it is driven by the usual cranks and connecting rods. The picking-stick is moved by the pull of a strap fixed to one arm of a bell crank lever. The other arm of the lever is flattened, and is brought by the movement of the lay against an arm fixed to a shaft which is turned through an angle of 90 deg. every pick, so as to pick the shuttle from either side.

Both the letting-off and taking-up motions are of the ratchet and worm kind, but in the former there is a finger which presses against the warp beam and limits the motion of the pawl, so that the feed is corrected for the

varying diameter of the roll. From the beam the warp passes over a spring-supported roller, so as to maintain the tension on the warp during shedding.

1340. Model of power loom. (Scale 1 : 4.) Woodcroft Bequest, 1903. M. 1776.

This loom has Bennet Woodcroft's adjustable cams or tappet-plates for rearranging the pattern; five plates and treadle levers are employed. To keep the fabric to its full width a simple form of temple, to be moved by hand, is provided.

1341. Power loom. Presented by Messrs. J. Harrison & Sons, 1858. M. 137.

This is an example of an ordinary plain loom fitted for driving by power. Four tappets, on a shaft which turns at a quarter the speed of the crank shaft, move the heald-shafts in the usual way; with this arrangement a four-thread twill can be woven.

Between the crank-shaft and the tappet-shaft there is an intermediate one, upon which is a cam for actuating the picker that drives the shuttle. A small conical roller fixed to an arm on the lower part of a vertical shaft, whose upper end carries the picking-stick, is held in contact with the cam, and the edge of the latter is bevelled to suit the conical roller. The cam is so shaped as to give a quick swing to the picking-stick, which is connected by a leather strap with the picker that throws the shuttle.

To protect the warp if the shuttle does not box, there is a loose reed motion. The upper rib of the reed is held in a groove in the lay cap, so that it can turn when the lower rib moves backwards. A bracket, fixed to a rod beneath the sole running the whole length of the lay, supports a rail which bears against the lower rib. It is held there by a flat spring, pressing upon a finger fixed to the same rod. A lever, also fixed to this rod, carries a roller which runs on a bent spring, to keep the reed steady when the shuttle is passing. Should the shuttle stop in the shed, the lay when beating up swings the reed backward, the finger turns the bracket, and its point comes into contact with a roughened surface on the stop rod, which it then pushes out of the notch and the belt is guided on to the loose pulley. In order that the reed may be quite firm whilst beating up, a curved arm fixed to the rod which carries the rail is so arranged that, when the shuttle has boxed and the reed is in its place, it shall be pressed upon by the lower surface of a chisel-edged piece fixed to the framing; one of these arms is at each end of the lay.

The arrangement for stopping the loom if the weft should break is the usual weft fork and grid, described in connection with No. 1349. The requisite tension on the warp is given by a rope coiled round the warp beam at each end, and attached to a flat spring fixed to the loom frame. When weaving heavy cloth the ropes are connected with a lever acted upon by the lay at the time when the heald-shafts are being moved; by this means the warp is slackened when the shed is opening, and tightened when it is closing. The cloth is wound up as it is woven, by a ratchet wheel and spur gearing driven from one of the swords. It is wound upon a roller whose ends rest upon those of weighted levers that keep the cloth roller in contact with the roughened roller. A self-acting temple keeps the cloth out to a uniform width; it consists of a roller fluted at each end, one cut with a right-handed and the other with a left-handed helical groove.

1342. Model of power loom. (Scale 1 : 2.) Presented by W. E. Taylor, Esq., 1862. M. 824.

This loom is a good example of the ordinary power loom, but has Mr. Taylor's improved mode of driving the lay and shuttle race. By using a very short connecting rod, the lay moves very slowly when back, but quickly when beating up the weft. One half of the lay is fitted with a

connecting rod of the usual length, so as to show the different action of the very short one. There is the usual self-acting temple to keep the cloth out to the proper width, and self-acting arrangements for stopping the loom, in case the shuttle does not run fully home into its box, or if the weft should break.

1343. Model of power loom. (Scale 1 : 3.) Lent by the Society of Arts, 1867. M. 1755.

This is a model of a plain calico loom, invented by G. White, of Glasgow, about 1829. Its chief features are that the shuttle is picked by springs which give a uniform throw, irrespective of the speed of the loom, and that the levers and cams are all driven from one shaft.

From the driving shaft, motion is taken through a crank and connecting rod to an upright shaft, to which is keyed a horizontal arm with two rollers upon it. One of these causes an arm, centred below, to rock through a small angle, and so give motion to the healds; it also moves a long horizontal rod endways, thereby compressing springs which pick the shuttle. The other roller oscillates a frame connected with the lay, and so effects the beating up.

The cloth is taken in by motion derived from a ratchet wheel, the pawl of which is worked from the horizontal arm, which gives motion to the healds and lay. The movement of the pawl is controlled by a finger, which presses upon the cloth beam, so that less motion is communicated to the beam as the diameter of the roll increases.

1344. Model of proposed power loom. (Scale 1 : 6.) Presented by J. E. Hodgkin, Esq., 1898. M. 3019.

This form of loom was patented by Mr. S. C. Salisbury in 1860; it was tried on a practical scale with some success, but was ultimately abandoned. The chief features of the loom are the shape of the shuttle, and the method of driving it, whereby the beating-up motion of the slay is dispensed with.

The shuttle is moved to and fro in the race by a roller, upon which it rests; this roller is carried on a frame that is reciprocated horizontally along guides by a pin projecting from the side of an endless belt, that passes over end pulleys, and is continually driven by power. The pin on the belt engages in a vertical slot in the reciprocating carriage, moving in the slot as it passes round the pulleys at the end reversals of its motion.

The construction of the shuttle is better seen in the larger detached model of the same. It is supported and guided by friction rollers, while the spool of weft is carried sideways through the reed. The weft thread leaves the shuttle centrally at its front, and passes between grooved rollers which press it into the shed, thus avoiding the use of a beating-up motion for forcing the weft home.

The headles, harness, and reed are of the usual construction, as are also the drums and rollers for the warp threads, and for the finished yarn. The motions for all of these parts are, however, derived from a pair of connected levers that are moved by the reciprocating carriage at each end of its travel; from these levers the motion is transmitted by segmental gearing and the usual ratchet feed motions.

1345. Model of power loom. (Scale 1 : 2.) Lent by the Society of Arts, 1869. M. 1756.

This is a model of a loom that will weave plain calico or checks; it has two tappets, and a double shuttle-box, so that two colours of weft may be used.

The shedding is open, and the tappets work negatively. They are moved by cords passing over segmental arms, fixed on two shafts which are rocked by an oscillating frame, operated by a cam on the lower shaft. The picker at each end is moved by cords attached to an arm fixed to a pulley, which is turned through a small angle by a leather strap, whose ends are pulled down

alternately by cam-moved levers. To move the shuttle-boxes, a spur wheel, driven from the lower shaft, carries a cam on its face, which acts upon a horizontal lever that depresses the boxes. When released, the shuttle-boxes return to their normal position through the action of a spring, attached beneath the sole of the lay. The letting-off motion is governed by a rope brake, and the taking-up arrangement consists of a ratchet wheel and gearing, moved from the crank shaft.

1346. Model of power loom. (Scale 1 : 2.) Lent by Messrs. Platt Bros. and Co., 1892. Plate VI., No. 4. M. 2453.

This represents a modern plain loom for weaving calico, and is in complete working order with the unfinished work in position. In most respects, it resembles the earlier examples, somewhat modified by accumulated experience, and its size is such as to show very clearly the general arrangement of a power loom.

To keep the warp threads tight during the interval when the shed is closed, the bar over which they pass from the drum or warp-beam, is given a swinging motion, by a lever at its end rocked by a cam on the crank shaft. The frictional resistance to the rotation of the warp-beam, required to keep the warp threads tight, is given by weighted chains passing round smooth pulleys, but is also increased by the large bearings provided. The temples, which secure uniformity in the width of the cloth, are carried on the beam by sliding guides fitted with springs. The finished cloth is wound in by a roughened roller round which it wraps through an arc of 240 deg.; it then passes round a guide roller and is wound on to the finished cloth roller below. This roller is forced against the roughened roller by springs, so that it winds in the cloth at a uniform rate irrespective of its diameter. There is a weft fork that automatically stops the loom when the shuttle thread breaks or runs out, and on the back of each shuttle box is an arrangement of levers that stops the loom if the shuttle does not go completely home in either box. These automatic stoppages are made by a trip gear that, when anything is wrong, releases the starting lever from the driving position, and under the action of a spring this throws the driving belt on to the loose pulley, at the same time applying a powerful brake to the crank-shaft, so as instantly to arrest the motion.

1347. Model of loom for weaving sacks. (Scale 1 : 8.) Lent by the Society of Arts, 1867. M. 1758.

This is a hand loom invented in 1802 by Thomas Clulow for weaving two fabrics by a single shuttle, so as to form sacks or other cylindrical articles without a seam, owing to the selvedges being common. The shuttle passes first through the top warp, and then through the lower one, so that the weft thread passes continuously round the sack. The bottom is closed by working the two fabrics into one for a short length.

1348. Model of loom for weaving fishing nets. (Scale 1 : 4.) Lent by the Society of Arts, 1867. M. 1759.

This machine was invented by Mr. J. Robertson, of Edinburgh, in 1806, and at the time received considerable attention. The model only makes a row of five meshes, but the actual looms were to be 3·5 ft. wide and to make 33 meshes in this width; the length of the net was unlimited.

The loom has a series of warp threads, each passing through a separate curved tube carried on a swinging frame, while across the framing extends a race in which is a like number of mounted bobbins or shuttles which are simultaneously moved sideways by a handle. At the back is a swinging and sliding frame containing a series of hooks which is so manipulated by the operator as to crochet a knot in each of the warp threads, and through these knots the shuttle threads are passed.

1349. Weft fork. Presented by Thomas Sibley, Esq., 1861.
M. 361.

This is a detached example of a weft fork, which is part of an arrangement for stopping a loom if the weft should break. It can be seen in position in Nos. 1338, 1341, and 1342.

This device is used in all plain looms at the present time, but for fancy looms, where several shuttles are used and several picks made from the same side consecutively, it does not give a sure means of stopping if any one of the shuttles breaks its weft. For such looms a centre weft fork is applied, an example of which can be seen in No. 1355.

At one end of the fork there are prongs, and at the other end a hook; the fork is nearly balanced on a pin, the prong end being left lighter so that the hook tends to fall. The pin is fixed to a rod attached to a bracket on the stopping lever which, while the loom is running, is retained in a notch. A bell-crank lever, with its upper end notched so that it can catch the hooked end of the fork when both are at the same level, is oscillated by means of a cam on the tappet or picking shaft. At one end of the shuttle race, in the reed frame, there is a grid between which the prongs can pass when the lay moves up. If the weft be unbroken, it lies across the grid and causes the fork to tilt up the hook, so that the oscillating notch does not catch. If the weft be broken, however, the prongs go through the grid and the hook is caught by the notch, so that the stopping lever is moved out of its notch and sprung to the end of its slot. The belt fork connected with the stopping lever throws the driving belt on to the loose pulley, and at the same time applies a brake, so that the loom is stopped at once.

The feature of Mr. Sibley's fork, patented in 1860, is the method of supporting it; with the object of reducing friction, and also taking up any slackness that may arise, the axis is carried between cone-centres.

1350. Reed hooks. Presented by J. Parr, Esq., 1908.
M. 3559.

The reed-hook is used by the weaver, in case of breakage of the warp thread, and, after piecing on a new bit, to pass the end through the healds and reed. The hook is simply a short length of flattened wire, bent at a slight angle with an inclined saw cut in which to hold the thread. The larger hook is for fine, and the other for coarse goods.

1351. Various shuttles for looms. Contributed by Messrs. J. Harrison & Sons, 1862. M. 633.

Shuttles for looms of various classes are shown, some opened and some with the cop of weft cotton in position. A later form of shuttle is seen in No. 1319.

1352. Shuttle for narrow fabrics. Contributed by W. E. Newton, Esq., 1862. M. 634.

This is an example of a shuttle patented by Archibald Turner in 1858. It is for use in weaving very narrow pieces, such as ribbons. The shuttle is shaped at its base to fit into grooves cut in the batten of the loom, the increased bearing surface thus secured reducing the length of shuttle necessary.

1353. Shuttle picker. Contributed by W. E. Newton, Esq., 1862. M. 650.

To drive the shuttle of an ordinary calico loom, a blow of about three foot-pounds must be struck for each throw, and this energy is transmitted to the shuttle by the picker. At even an ordinary speed of 200 picks per min., the wear upon the picker is serious, so that many materials have

been tried in place of buffalo hide, the material most generally employed. The picker shown is made of hard vulcanised rubber, and was patented in 1857.

1354. Samples of calico. Presented by C. W. Harrison, Esq., 1865. M. 980.

These two pieces of calico were woven in a pneumatic loom, by Mr. Harrison, in which the shuttle was driven by compressed air.

1355. Knowles's open shed fancy loom. Lent by Messrs. Hutchinson, Hollingworth & Co., 1889. M. 2275.

This loom belongs to the class known as dobby looms. A dobby is intermediate between a tappet and a Jacquard machine. It will weave patterns that are beyond the scope of a tappet loom more economically than they could be produced by a Jacquard.

There are 24 heald-shafts and eight shuttle boxes, arranged so that seven shuttles, each holding a different kind of weft, can be used Each heald-shaft is operated by a rod and strap attached to an arm of a bell-crank lever or harness-jack, connected near the middle point of its upper arm with a connecting rod which is jointed at its other end to a gear or disc having teeth; the disc acts as a crank in moving the connecting rod and harness-jack. The gear is mounted on the end of a vibrating lever, centred at its outer end; this lever rests upon the pattern chain, which consists of a series of rollers and collars mounted on spindles; a roller raises the vibrating lever, and a collar allows it to fall, carrying the gear with it. The latter is placed between two cylinders, which revolve in opposite directions, and have teeth upon half their circumferences. The gear has a tooth missing at one side, and exactly opposite there is a gap of four teeth. When the vibrating lever rests upon a collar, the gear is brought into contact with the lower cylinder, and if the small gap be below, the teeth of the lower cylinder carry it round for half a revolution, and so a heald-shaft is lowered. If the larger gap be below, the cylinder does not move the gear, and the warp threads connected with this harness and heald-shaft remain where they were. When a roller comes beneath the vibrating cylinder and raises the gear to the upper cylinder, the smaller gap being there, the heald-shaft is raised. There is a complete set of rollers and collars on the pattern chain; and a vibrating lever, gear, and harness-jack for each heald-shaft. The outer arm of the bell-crank lever or harness-jack is connected with the lower shaft of the headle, to pull it down, the upper arm raising it. By pulling a bar near the harness, all the jacks are raised, and the gears, being brought to the upper cylinder, will be turned until all the heald-shafts are level.

To bring into operation the drop-boxes in which the shuttles rest, four gears and a pattern chain, similar to those above described, are used. The connecting rods from two adjacent gears act upon two levers, one of which carries a pulley, over which passes a chain from the other lever to the shuttle boxes on one side. By means of the four possible combinations of positions of the two levers which work together in each set, the four different movements necessary to bring each of the shuttle boxes level with the race are given to the chain in the order determined by the pattern chain. A fifth gear, operated by a fifth set of rollers and collars on the pattern chain, is connected by levers with two clutches on the bottom shaft, through which the shuttles are picked; when either side is not required to pick, its clutch is put out of gear.

The shuttle is thrown by a lever, receiving a quick motion from a bowl on the lower shaft, which acts upon a cam plate. The lay vibrates upon two swords centred below; it consists of a heavy beam, to which the guides for the shuttle boxes at each end are fixed. The reed forms the back of the shuttle race, and consists of flat wires or "dents;" between each two dents one or more warp threads pass. When the shuttle has carried its weft

through the shed formed in the warp by the harness and healds, the lay moves forward and beats the weft up by means of the reed into close contact with the cloth already made. If the shuttle, after being picked, does not reach the opposite box, or go fully home, a projecting piece on the lay catches a bar which runs across the loom under the breast beam and is connected with the stopping lever.

To stop the loom when the weft breaks there is a centre fork arrangement. This consists of a light fork placed in the centre of the reed space; the prongs lift to allow the shuttle to pass, and then fall until they feel the weft; if there be no weft, however, the fork goes further, and so lifts a piece which, as the lay moves forward, catches a finger on the bar connected with the stopping lever.

There are two beams for holding the warp, each being turned independently by ratchet and worm, the pawl of the ratchet receiving its motion from that of the lay. Each set of warp threads passes over a polished roller held in a bracket at the end of a bell-crank lever, the other end of which is weighted, so that a uniform tension may be maintained in the warp as it is acted on by the harness, and as the cloth is taken up. The taking-up motion is also derived from the swing of the lay, through a pawl and ratchet wheel.

1356. Model of Jacquard apparatus. (Scale 1 : 2.) Lent by the Society of Arts, 1867. Plate VI., No. 7. M. 1757.

This is a model of a loom with a Jacquard apparatus attached, the latter being used to raise and lower the sets of healds through which the warp threads pass, in the order required for weaving complicated patterns that are beyond the scope of tappets. As seen in this model, the machine contains Falcon's prism and a chain of punctured cards for determining the pattern, together with his needles and hooks invented in 1728. The griffe, or arrangement of standing bars which catch the hooks and lift them, was invented by Vaucanson in 1745.

The griffe is reciprocated vertically by the crank-shaft of the loom through levers. Fixed behind the guides of the griffe on each side is a plate, curved on its opposite sides; two rollers on the horizontal sliding piece, which hold the card cylinder, are in contact with the curved plate, one on each side, and by this means the cylinder is reciprocated horizontally. The prism is turned through a quarter of a revolution at every pick by a catch, centred at one extremity of a bell-crank lever driven by pins fixed to the griffe guide bar.

There are 100 needles arranged in four rows of 25 each. Each needle passes through a needle board at one end, and at the other end projects into a spring box, where its end is pressed upon by a small helical spring tending to force it towards the cylinder. A loop is formed in each needle at its middle, and through this the vertical hooks pass. In order to keep the ends of the hooks in position for being lifted by the griffe, they are bent at the base, and the U thus formed rests in a groove when the needles are down. The healds are attached to the bases of the hooks.

Through each face of the prism as many holes are drilled as there are needles, and in corresponding positions. The pattern cards have holes through them at points opposite to the needles connected with those hooks which are to be lifted in any pick, and there is one card for each pick of weft in the pattern. When the prism moves in towards the needle board, the cards press upon the ends of the needles and push them back, but the needles which are opposite to the holes are not moved, and thus the respective hooks are moved into position for being lifted or missed by the bars of the griffe when it next moves up. Each heald is held down by a hanging leaden weight. The eye for the warp thread is formed in a small link of brass, instead of being formed in the heald string, as is now the practice.

The loom to which the Jacquard machine is attached in this model is weaving a narrow silk ribbon. There is no special feature in the loom, except that the picking stick is operated by a double-grooved cam.

1357. Woven portrait of Joseph Marie Jacquard. (1752–1834.) Woodcroft Bequest, 1903. M. 1777.

This complex pattern was woven by a Jacquard loom with a single shuttle.

1358. Jacquard apparatus. Woodcroft Bequest, 1903. M. 1780.

This is an example of Bennet Woodcroft's Jacquard, and is similar to No. 1359. The needles are, however, operated by pegs, fixed in a pattern chain of boxwood strips, which take the place of the ordinary cards. The chain passes round a four-sided prism, and the flat ends of the needles are pushed by the pegs as the prism moves inwards, and so press back the corresponding vertical bars. Different patterns are arranged by moving the pegs, which in this example control 16 heald-shafts.

1359. Jacquard apparatus. Woodcroft Bequest, 1903. M. 1779.

This is an example of a Jacquard machine designed by Bennet Woodcroft; it is similar in its general mode of action to No. 1356.

Cards passing over a square prism determine by their perforations which of the 27 needles shall pass into the holes in the prism. An upright bar passes through a slot in the needle, and is moved sideways when the latter goes into a hole. There are two shoulders on each vertical bar, and two griffe-blades and racks operated by a pinion. This pinion is turned by a sector wheel, which gears with a sector on the end of a long lever, which receives its motion from the tappet plate of the loom. One griffe-blade acts upon the vertical bars to lift them, and the other to depress them, according to whether they are moved to one side or the other by the needles. The latter are pressed in towards the prism by helical springs.

A hook centred on the frame pulls the prism round a quarter of a revolution each time the latter moves out. The prism is swung to and fro by levers driven by an arm on the sector wheel. Two flat stops, held down by springs, lock the cylinder in position.

1360. Model of Jacquard apparatus. (Scale 1 : 4.) Woodcroft Bequest, 1903. M. 1778.

This is a model of an apparatus designed by Bennet Woodcroft (Letters Patent No. 7529, A.D. 1838) on the Jacquard principle, but to work in conjunction with his tappet loom.

Instead of single healds being operated by the Jacquard needles, in this example there are only six needles, and each of these operates a heald raising many warp threads at the same time.

The driving is from the tappet plate, not shown in the model, through the steel levers which are connected with a horizontal shaft cut into a six-sided prism, which corresponds with the "griffe" in the ordinary Jacquard machine. It is fixed on each side to a sliding bar whose lower end forms a rack, and a pinion gears into this rack and into another one which is connected with a second griffe similar to the first. The Jacquard prism has four faces, and is moved to and fro by bell-crank levers operated by the racks.

The needles have slots at their centres through which the ends of six vertical bars pass. Each bar has two shoulders upon it turned in opposite directions. One of these would be caught by the lifting griffe if the needle had pushed to that side: if to the other side, the other shoulder would be caught by the second griffe, and so the six horizontal levers are operated to lift or depress the six healds in the order required by the pattern.

1361. Jacquard machine. Received 1891. M. 2259.

This is an example of a modern Jacquard machine, with two prisms and two sets of needles and hooks, 400 of each in each set. The needles of each set are arranged in eight tiers of 50. There are two griffes with eight blades each; the two sets of blades alternate with each other from front to back, and are inclined in opposite ways as are also the rows of hooks that they lift, but both griffes are connected with a common crosshead above, by which they are simultaneously lifted once for every pick of the shuttle.

The prisms are swung in frames connected by adjustable bars, so that one swings in while the other swings out, and this motion also rotates them, by a pawl engaged with a four-toothed pinion formed on the axis of each prism. The warp threads that are to be lifted for one pick are determined by the card on one prism, and those to be lifted the next pick by the card on the other prism; the cards are therefore arranged in two sets, one containing the odd and the other the even cards in the order of the pattern.

A spring box is secured to the frame, on the same level as each prism but on the opposite side, containing a spring to return each needle; the needles pass freely through the mass of upright wires or rods, except that each needle loops round its particular upright wire and so is able to deflect it.

KNITTING MACHINERY.

Knitting differs from weaving in that only a single thread is used, a surface being obtained by the continuous interlooping of the thread in a way that is most obvious in the form of knitting known as crocheting. The result of this looping, together with the absence of weft or warp threads, is that the cloth formed is extensible in every direction, so that a knitted garment can be put on, and will fit the body in a way that is quite impossible with a woven fabric that has been cut to shape and sewn.

Knitting is the most modern of the textile processes, and although now universally practised it is supposed to have originated in Scotland as recently as the 15th century; as the tools required consist only of a single crochet hook, or of the four sticks or wires known as knitting needles, it is remarkable that the more complicated weaving process should have so long preceded it. Net-making is, however, a universal art of the greatest antiquity, and in some respects resembles knitting, but requires a shuttle.

The first machine to knit mechanically was the stocking frame, invented by the Rev. William Lee in 1589, in which was introduced the fundamental principle of a successful knitting machine, which is that a separate needle shall be used for each loop; in this way he at first made flat webs which by being sewn together along their selvedges made a cylinder. He afterwards found the means of producing shaped articles by throwing out of action some of the hooks as required. Lee, failing to get support in this country, took his machines to

France, where he settled successfully at Rouen, and in 1640 his frames were adopted in Leicester.

The knitting by machinery of the ribbed surface, which gives so much greater elasticity in one direction, was first accomplished by Jedediah Strutt in 1758 by the introduction of a second set of needles at right angles to the first set. The circular knitting machine by which cylindrical work could be produced without seams was brought into a form suitable for practical use in 1845 by Mr. Peter Claussen, but such an arrangement had been suggested much earlier.

The needles in a stocking frame or knitting machine have hooked ends, with the hook extending backward to form a long spring barb, or beard, which is capable of being pressed close to the body of the needle, so that the loop of thread on the needle can be pushed over the hook when the beard is depressed, or will be retained on the hook if the beard is up. In this way the loop in the hook is drawn through the loop that has been formed round the needle. In 1858 Mr. M. Townsend introduced the latch-needle, in which the beard is replaced by a finger hinged to the needle; this arrangement simplifies the work of the machine, and the small knitters for domestic use usually have needles of this type. It has been stated that a hand-knitter can work 100 loops a minute, that Lee's machine did 1,000 to 1,500 loops, and that the circular frame does from 250,000 upwards, depending upon the total number of needles.

Knitting is one of the few industries in which the factory system has not completely displaced home industry, and the tendency seems to be to extend the employment of small machines worked by hand or treadle at the operator's home rather than the larger installations of a factory. The knitting and hosiery industries are now of the greatest importance, and include the manufacture of underclothing, caps, stockinet cloth, &c., while the bags, or shirts, in which frozen meat is imported, and the mantles for the Welsbach burner (*see* No. 1681–3), are examples of the varied application of this interesting process.

1362. Manual stocking frame. Lent by Messrs. Cooper, Corah & Sons, 1897. Plate VII., No. 4. M. 3007.

This is a knitting machine for producing a flat web, and is somewhat similar to the original frame invented in 1589 by the Rev. W. Lee, although this example was made about 1770, and represents the stocking frame in general use till 1840.

There is a horizontal row of needles, with hooks, or beards, turned upwards, which, however, can all be depressed by a bar above them, known as the presser, so as to let the thread pass over the hooks. Between each needle is a notched steel plate, or sinker, and the alternate plates are formed into two sets, known as jacks and leads, the members of which can be successively raised or lowered. In working the

apparatus, the operative places the thread loosely above the needles, and under the notches of the sinkers. He then depresses the jacks, so causing the sinkers to carry the thread between alternate pairs of needles so as to form a series of loops below. The lead sinkers are next lowered to half the depth of the jacks, whilst the jack sinkers are raised until the thread is equally sunk between all the needles. The sinkers are now all brought forward and the newly-formed loops left under the beards of the needles. The last set of loops of the fabric already finished is around the needles and held by the sinkers, so that by closing the beards and moving the sinkers forward the previous course of loops is slipped off the needles; the newly-formed loops in the beards have now only to be forced by the sinkers to the back of the needles for everything to be ready for the next row of loops to be added as before.

The downward movement of the presser bar is derived from the central treadle, the return being secured by a spring. The motion of the jack sinkers is obtained from a cord connected with a flywheel which is reciprocated by two treadles, while the lead sinkers are moved by two plates at the sides of the machine, which depress them simultaneously.

A diagrammatic model, M. 3094, made in the Museum workshop, and illustrating the principle of the stocking frame, is also shown.

1363. Straight knitting machine. Contributed by Sir Joseph Whitworth, 1860. M. 585.

This machine, patented in 1846 by Sir Joseph Whitworth, is a greatly improved form of a machine jointly patented by himself and Mr. John Wilde in 1835. It is intended for straight work, but owing to the ease with which the width, or number of stitches in a row, can be varied, it is suitable for shaped articles.

The machine consists of a cast-iron frame carrying a long slide holding the knitting needles, which hook upwards, but have no beards. Behind the guides is a horizontal shaft with four cams on it, and arranged for driving by hand or by belting. The bobbin of thread or yarn is supported in a frame at the back, and is pressed by a weighted lever that gives the necessary tension; beneath this bobbin are supports for a second one, the thread from which could be passed through the machine with the other thread when knitting portions of garments requiring extra thickness. The stitch is made by the hooked needles and three moving pieces: one is the feeder or eye that leads the thread between the needles and round the hook; the second carries the hook that lifts the back thread on the needle, up and over the hook of the needle; the third is a presser that forces back the work from the hooked end of the needle.

The feeder that carries the thread leads it horizontally between the two nearest needles; the row of needles then advances, and the thread is led outwards again, so getting hooked by the needle; the lifting hook then moves along the upper surface of the needle, which is grooved, and lifts the loop from the previous row over the hook of the needle, so looping it over the thread that is still retained in the hook of the needle. The presser now swings horizontally, and then descends between the lifting hook and the needle, so removing the loop from the lifting hook, and then by a backward motion presses the work back along the needle; at the same time the needle forms a loop round the presser, which loop is retained until the thread has been led by the feeder round the next needle hook. The intermittent movement of the slide holding the needle is given by a rack in which engages a lever from the largest cam; the groove of this cam has a swinging tongue in it, and when the stops limiting the travel are reached, this tongue is automatically thrown over so as to reverse the feeding direction of the cam.

These motions are given by cams on the main shaft; the complex movements of the presser are obtained from a single cam and a double one, the arrangement being equivalent to three cams that give a controlled motion in three directions at right angles.

1364. Circular knitting machine. Lent by Messrs. Cooper. Corah & Sons, 1897. M. 3008.

A circular machine for knitting cylindrical objects was first patented by Sir M. I. Brunel in 1816, but many years elapsed before the construction was sufficiently perfected to enable the high speed possible by such an arrangement to be utilised. The example is an early form of the construction now found in the machines of this class, and was built for knitting the material used in making stockings; the large circular machines now employed for making knitted cloth have the ring of needles arranged horizontally, while the finished pipe of fabric descends vertically.

The machine shown has two knitting heads secured on a single frame and driven by bands from pulleys at one end. In each head the needles are arranged horizontally in a vertical ring, with their hooks, or beards, turned outwards. As the ring revolves these needles act as wheel teeth, engaging with the teeth of three skew-bevel pinions which turn freely on inclined axes secured to the main framing. The first of these pinions presses the thread between the needles and also under the beards; the second pinion more uniformly distributes the thread amongst the loops thus formed, and a fixed roller now closes the beards, whilst the third pinion pushes the loops on the back of the needles over the beards, thus virtually drawing a new loop through each loop of the preceding row, as required in the knitting process. A stationary circular wedge held within the ring of needles forces the work backwards along the needles; it is thus ready for the commencement of the formation of the next series of loops by the insertion of the thread under the needle barbs. The finished work is kept tight by the horizontal pull of a weighted cord.

In the large modern machines previously referred to, several threads and groups of wheels are simultaneously being acted upon by the single ring of needles, thus greatly increasing the output.

1365. Circular knitting machine. Contributed by W. Smith, Esq., 1860. M. 584.

In this early circular knitting machine the needles are arranged vertically, and held by a wide flexible band or chain, inside of which the finished work passes downwards. At the front of the machine is a clip that holds a length of the band equivalent to 12 needles, and by the motion of the machine the band is forced through the clip a distance equal to the pitch of the needles at each stroke. At the top the needles are hooked outwards, and over the centre of the clip rises and oscillates a hook that lifts a thread over a needle; while two side levers keep down the work, another lever leads the thread under the hooks of the needles.

The freedom of the needles and the way the thread is led cause this machine in its working to resemble somewhat knitting by hand; it appears to have turned out good work, but the stitch-at-a-time action probably rendered it somewhat slow.

1366. Circular knitting machine. Woodcroft Bequest, 1903. M. 28.

This machine was patented by Mr. J. A. Tielens in 1842, and is designed for circular work. It is suspended from a vertical frame, and the needles are arranged radially in a horizontal circle with their barbs, or beards, upwards; the closing of the beards at the right time is performed by an inclined roller. Between the needles are vertical jacks, worked by a cam below in such a way that they drag down and retain the thread as required for the operation of knitting; a central cam gives to the jacks a radial motion that enables them to lift the loops off the needles.

The machine is worked by a winch handle at the top, and the finished knitting is wound upon a roller carried on a suspended frame that pulls down the work as completed.

1367. Circular knitting machine. Lent by Messrs. W. H. Dorman & Co., 1889. M. 2263.

This is a modern circular knitting machine, arranged for driving by hand or steam power and suitable for knitting stockings or similar articles.

It has a set of vertical needles, raised and lowered by a revolving cam, which engages with a projection near the bottom of each needle; the needles hook outwards, and are provided with hinged latch pieces, which, when up, mask the hooks. As each needle is raised, the loop already within the hook, being pulled down by a weight suspended from the end of the fabric, opens the latch piece, and as the needle continues to rise, the latch piece is pressed completely through the loop. When the needle is lowered this loop pushes the latch piece up and passes off the needle.

There is a rotating arm carrying a guide piece, which leads the threads into the hooks whilst the needles are being lowered, and also prevents the latches from closing too soon. The needles move up and down in slots, between which there are ridges which act as sinkers in forming the loops. As the needles are lowered, the newly formed loops remain in the hooks, whilst the previous course of loops pass off the needles, so that the new loops are drawn through those previously completed as required in the operation of knitting.

To give the ribbed pattern, necessary where extra elasticity is required, a second set of similar needles is provided, which, however, move radially in a horizontal plane. These needles are arranged at regular intervals between the vertical needles, and are moved in and out by a cam. They have their hooks upwards, and form a series of stitches in which the direction of looping is reversed. In each of their stitches the newly formed loop is drawn through the previous one in the opposite direction to that in which the stitches are formed by the vertical needles, but the ribbing needles form their stitches by the same operations as the vertical ones; the nature of the ribbing loops is determined, however, by the height of the cam disc by which their needles are moved.

1368. Elementary Millar loom. Lent by the Millar Loom Co., 1902. M. 3220.

This straight knitting machine or knitting loom, patented by Mr. John Millar in 1891–8, was designed for the purpose of making a more compact and less elastic cloth than that produced by simple knitting.

The structure of the fabric produced, shown in the loosely knitted enlarged specimen adjacent, consists of a series of straight longitudinal warp threads, a series of straight transverse filling threads laid continuously along under the warp threads, and an upper series of weft threads alternating with the filling threads. The knitting threads are looped singly into each other, and pass between and around the warp threads and under the filling threads, thus holding the latter in place.

In the explanatory machine shown there are one set of knitting needles, two bobbins of weft and one roller of warp threads. Each needle consists of a hook provided with a swinging latch and is guided vertically in a slot formed in the needle bar, whilst a horizontally reciprocating slide, provided with a cam slot, engages with lugs formed on the lower part of the needles and so raises and lowers them successively. An upper cam block, driven from the main slide by spring catches actuated by cam plates at each end of the stroke, carries the filling thread guide, and moving along under the warp guides thrusts them forward at the right instant, whilst the guide over the needles carries the knitting thread. By these arrangements the relative positions of guides and elevated needles are maintained during both strokes, and the warp guides are successively thrust outward just in advance of the filling guide. At the same instant the needles commence to rise above the needle-bar, and the filling thread is laid under the warp thread behind the needles, and upon the previously formed knitting thread loops around

them. The guides then draw the warp threads back across the filling thread, and this is followed by the introducing of the knitting thread, which is at once converted into loops by the hooks of the advancing needles being drawn through the previous loops which, by means of the latches, slip over them.

A complete Millar loom consists of a framework carrying two straight sets of vertical reciprocating needles arranged in groups and actuated by revolving cams, a series of mounted and guided warp threads, an upper series of knitting threads, and a lower series of filling threads. It has as many pairs of bobbins as there are groups of needles, and they are attached to endless chains which carry them continuously round the whole range of needles, by which arrangement the speed of working is increased and two connected webs or widths of fabric are simultaneously produced.

FINISHING TEXTILE FABRICS.

After having been woven into cloth by the loom, very many materials require further treatment to fit them for their special uses; such processes are here arranged under the head of finishing, with which are included the dyeing and printing of fabrics.

Washing, saturating with various sizes, and subsequent calendering give to calico goods a smooth surface, but, owing to the increase of weight that can be obtained by heavy sizing, the process has sometimes been carried to great excess. Beetling is a process by which a cotton fabric is rendered softer and also consolidated, usually by some form of drop hammer or stamp, but a similar action has been obtained by chequered rollers (*see* No. 1369). With woollen materials it is usually desired to obtain a finish that hides the individual threads of the warp and weft. This is given by brushing or treating the surface with hot water, by which treatment the stray fibres projecting from the threads are matted together so as to form a nap that conceals the individual threads; when worn off it leaves them visible and gives the appearance known as threadbare. An early machine for raising a nap or pile is seen in No. 1370.

Colouring or dyeing is chiefly a chemical process, the machinery employed being usually simple; three examples of washing or dyeing machines for calico are in the collection (*see* Nos. 1371–3).

Printing is a means of embellishing textile fabrics far more cheaply than by weaving the pattern in a loom. For many years the printing was done from heavy wooden blocks having the pattern on their faces, those parts being cut away where no colour was required. The blocks were furnished with colour by placing them face downward on a cloth stretched on a frame which floated on gum-water, and on this cloth the printer continuously brushed the required colour. Such blocks are seen in Nos. 1374–6. When the pattern required more than one colour these were supplied successively by different blocks

(*see* No. 1378). Instead of applying coloured matter, however, the printer frequently used a chemical mixture known as mordant, which, where present, acted on the dye when the article was subsequently immersed in the dye vat; white spots were sometimes obtained by printing them with wax before dyeing, so preventing these spots from absorbing the colouring matter. In modern calico printing, however, rotary machines are almost entirely employed, the pattern being engraved on the copper surface of the roller (*see* No. 1382), and the impression taking place when passing between the printing and platen rollers.

1369. Model of beetling machine. (Scale 1 : 4.) Lent by Messrs. Ridgway, Bridson, Son & Co., 1857. M. 97.

Beetling is a process employed on certain cotton goods requiring the soft finish which is obtained by hammering or flattening the surface of the cloth.

This model shows a form of machine patented in 1855 by Mr. T. R. Bridson, in which, however, no hammering action occurs, but a somewhat similar effect is produced by the use of an indented roller.

There are three horizontal rollers, the top and bottom ones, which are smooth, being carried in sliding bearings, while the central one, which has on its surface diamond-shape projections, is rotated in fixed bearings. By this motion the cloth is wound off the upper roller and, passing round one side of the central roller, is then wound on the lower one; when this is full the motion is reversed, and so on until the desired finish is obtained. The upper and lower rollers are pressed against the central one by weighted levers, and in its repeated passages between the rolls the cloth is being pressed by the projecting surfaces of the central roll upon the soft padded surfaces given by the cloth on the winding rolls, so causing a uniform working of the material.

1370. Model of teasing mill. (Scale 1 : 8.) Received 1895. Plate VII., No. 1. M. 2749.

Teasing is a process for raising a pile or nap on the surface of woollen cloth by scratching the material with teasels, which are prickly seed balls covered with minute hooks that open and loosen the uppermost fibres when drawn over the cloth. Originally the teasels were set in a frame which was rubbed over the cloth by two men, but by arranging them on a cylindrical drum a more convenient method of teasing was developed, that led to the construction of the teasing or gig-mill shown. The model was constructed more than a century ago in the West of England, whence the gig-mill was introduced into France in 1802–7 by State assistance.

The mill has a large open horizontal drum, between the bars of which can be secured metal frames carrying teasel balls. The cloth is teased during its contact with the hollow drum while being wound from a roller above it to another below, and *vice versâ*. The upper roller and the drum are directly connected by spur gearing, giving a linear speed to the teasels of about 18 times that of the cloth. The lower roller is driven by the drum through friction gearing only, the contact of which is controlled by a lower lever. Each roller is in two lengths, and is provided with a claw clutch by which it may be released, and has also a friction brake.

As the teasing must be repeatedly performed before the surface is finished, the cloth when all wound on to the lower roller is wound back again on to the upper roller and so on, the direction of motion of the cloth being continually reversed, but owing to the form of a teasel, the teasel

cylinder must run continually in one direction only. This is arranged as follows: when winding on to the upper roller, the friction gear of the lower roller is open, the roller being simply retarded by its brakes; when winding on to the lower roller, this latter is driven by its friction gear, and the upper one, which is released by its clutches, is only retarded by its brakes, which are weighted to maintain the requisite tension on the cloth.

1371. Model of wash-wheel for calico printers. (Scale 1 : 4.) Contributed by Messrs. Hoyle & Son, 1857. M. 95.

This machine consists of a large wheel or drum divided into four parts by radial divisions. There is a large hole in the front of each compartment, through which the pieces of calico to be washed are introduced. At the back of the wheel is a circular slit through which a jet of water is directed from outside, so that as the wheel revolves on its axis the goods are thrown over and over in front of the jet of water, and also fall heavily to the bottom of the compartment, the combined treatment thoroughly washing them. At the outer edge of the back is a series of small holes through which the foul water runs off as each compartment passes the lower portion of its path.

1372. Model of washing and rinsing machine. (Scale 1 : 4.) Contributed by Messrs. Ridgway, Bridson, Son & Co., 1857. M. 96.

This machine, which was patented in 1852 by Mr. H. Bridson, is intended to wash and rinse calico in the piece, two lengths passing simultaneously several times through a tank, at the same time receiving a flapping motion to assist in the removal of impurities.

At the top of the tank at one end are weighted feeding rollers from which the calico passes to guide rollers at the bottom of the tank; it then passes horizontally to a revolving flat frame or wince, and back to another revolving wince round and under which it passes, to a lower guide roller, then upwards to an upper guide roller, and finally to a pair of squeezing or drying rollers over the tank. The squeezing rollers and the two winces are all connected by gearing, so that a regular flapping motion can be maintained. The level of the water is varied to suit the work upon which the machine is engaged; for washing it is considered that the material should strike the surface of the water, while for use in dyeing continual immersion is recommended.

1373. Model of dyeing apparatus. (Scale 1 : 8.) Contributed by Messrs. Hoyle & Son, 1857. M. 94.

This machine runs pieces of calico, whose ends have been stitched together into an endless length, repeatedly through dye liquor contained in a tank, so ensuring complete and uniform saturation.

There are two long dye baths, arranged in line with a space between for mechanism; over each bath is a square horizontal revolving prism, and at the bottom of each bath are two rollers. The baths are divided into compartments by open partitions to keep the calico pieces separate, and centrally along the bottom of the tank runs a steam pipe for maintaining any desired temperature. Above one of the immersed rollers is a sloping shelf, on which the piece being dyed rests in a pile that is being continually added to at the top and drawn from at the bottom, a great length of fabric being thus under treatment in each tank.

1374. Blocks for printing chintz. Received 1875. M. 1774.

There are seven cases containing specimens of the wooden blocks used for printing chintz by hand, as used in England about the year 1800. Each block consists of a mahogany or oak base with a thin face of the more expensive boxwood. The pattern is drawn in reverse on the boxwood and then cut into it, but a small border pattern shown has been prepared by the use of brass pins.

Block printing for textile fabrics with repeating patterns is now almost superseded by rotary printing from engraved copper rollers, such as shown in No. 1381.

1375. Blocks for printing silk and calico. Contributed by Messrs. Hoyle & Sons, 1857. M. 86.

Two blocks and a portion of a metal stereotype are shown. The blocks are built up of soft wood at the back, where are provided recesses by which a firm hold can be obtained with one hand when using them for printing. At the corners are pins by which in a repeating pattern correct register is attained.

The patterns are cut in small pieces of boxwood with which the block is faced, but fine lines and dots are rendered in metal tape or pins; in one case the pattern is outlined in copper tape, the solid portions being obtained by filling in the outlines with cement. In large patterns containing blotch-work the surfaces were often recessed and then filled in with felt, which readily took up the colour.

1376. Two-colour printing block. Received 1900. M. 3131.

This is a hollow block, built up in sheet iron, with handles on the top and provided on its lower face with projecting pieces corresponding with the portion of the pattern that is in the most prevalent colour. Within the block is a plate, pressed upwards by springs and provided with a knob by which it may be forced downwards; from the lower face of this plate project pins, corresponding with the portion of the pattern in the second colour, and passing freely through holes in the lower face of the block.

When the block is placed on an inking pad the fixed portions only are in contact with the colour; but when removed and the knob depressed, the second portion of the pattern becomes the more prominent, so that it can be inked on a second pad of a different colour. The block is thus charged with both colours, which can be simultaneously printed by placing it on the work and pressing downwards both the block and the knob.

Making the patterns in two portions, for different inkings, and placing them together when impressing ensures good register with rapid production, and is the device by which the Government stamps on patent medicines are printed.

1377. Model of calico printing machine. (Scale 1 : 6.) Maudslay Collection, 1900. M. 3123.

This is a platen machine patented by Henry Maudslay in 1805 to reduced the time and labour required in printing from blocks by hand (*see* Nos. 1374 and 1378).

The engraved block, or copper plate, is supported on a table which, by two eccentrics on a horizontal shaft, is lifted and powerfully pressed upwards against the calico whilst it is resting under a flat platen that forms the connection between the side frames. There are three blanket rollers, the upper one of which is in adjustable guides, while the front one is fluted, and receives a periodical feed motion by intermittent gearing driven from the eccentric shaft, so that after every impression the calico is carried through, by the blanket, a distance equal to the width of the block. The frame carrying the printing plate is in duplicate and hinged, so that while one plate is printing the other is in a convenient position for being inked; this arrangement also permits of printing in two colours. In the specification, arrangements are mentioned for drying the work by steam as finished.

The machine appears to have achieved considerable success, but was supplanted by the cylindrical form (*see* No. 1381).

1378. Model of block-printing machine for calico. (Scale 1 : 4.) Contributed by Messrs. Hoyle & Son, 1857. M. 89.

This is a model of a machine, patented in 1840 by Mr. R. Hampson, for printing calico from blocks. It is arranged for printing in five different colours, but can also be used for single work.

The block is supported face downward in a frame that slides in vertical guides; it is counterbalanced by a chain that passes over pulleys, and is attached to a weighted rod. The calico is supported on a blanket-covered table below the block, so that by lifting the rod the block descends by its own weight and so impresses the calico. On rails secured to the sides of the table runs a carriage supporting the inking arrangements, and after printing an impression on the calico the carriage must be pushed under and the block be lowered upon it for a fresh inking, before a second impression can be properly printed.

The calico is on a roll at one end of the machine, and after being printed passes over a hot-water or steam plate and round a long course, to dry it before it is wound up in a finished roll. The blanket beneath the calico is protected by a second calico piece which passes through the machine with the actual work. The machine is arranged for printing in five colours, which are shown on the inking carriage. The block is in five sections, and after each impression the calico is wound forward a distance equal to one-fifth of the width of the block, so that at each impression an additional colour is printed. The colour reservoirs and the spreading brushes are shown in position.

1379. Model of carpet printing machine. (Scale 1 : 8.) Woodcroft Bequest, 1903. M. 377.

This is a model of a machine, patented in 1839 by Mr. Joseph Burch, for printing from blocks on textile fabrics or paper. The machine and a modified form of it (*see* No. 1380) were first tried on a practical scale at Messrs. Crossley's works at Halifax.

The tapestry carpet or other material is wound on a roll that is well clear of the floor level; from the roll the carpet passes through a tension device and over a large drum, then over a printing table within the machine, and round another large drum. From this it returns at a lower level to a frame of 15 guide rollers, round which it passes with its printed surface always outwards; by this exposure it is sufficiently dried to be wound in a finished state on the roller in the centre of the frame.

The printing blocks, of which there are six in the model, are carried in frames which, by plate springs, are supported face downward on a large reciprocating frame which travels in a direction at right angles to that of the carpet being printed. When either set of blocks is over the printing table the reciprocating frame stops, and several spring pressers force the frames down under the action of a crank or toggle mechanism; the other set of blocks is at the same time over the inking tray upon which, by similar pressers, the blocks are forced downwards for inking; the printing pressers contain within them a trigger gear by which they are enabled to give a blow when down on the block.

Within the machine is a large endless apron or blanket, which forms an elastic covering for the printing table, and one which is being continually changed; with the blanket also passes an endless oilskin apron upon which the colour squeezed through the material being printed is deposited, and this apron is being continually washed and dried by an arrangement of guide rollers, &c. at one end of the machine.

The fabric is advanced by a step motion given to the main drums, driven by a cam on the main shaft; a similar motion traverses the blanket and oilskin apron. The reciprocation of the carriage and most of the motions are derived from cams. By the arrangement of the blocks six different colours

can be printed at the same time by this machine, or two pieces of fabric may be passing through the machine at once and receive different patterns, each of which contains three colours.

1380. Model of drugget printing machine. (Scale 1 : 8.)
Woodcroft Bequest, 1903. M. 378.

This is a model of a machine, patented in 1843 by Mr. Joseph Burch; it is a simplified form of his earlier machine, No. 1379, and although stated to have been designed for printing druggets, it is also suited for general block-printing in colours. His patent also describes an arrangement that embodies the important features of the modern cylinder machines for calico printing.

The general object of the design is to ensure accurate registering of the several blocks by which the pattern is printed, and to prevent the accumulation on the table of colouring matter that has been pressed through the work in progress.

In the model six blocks are mounted three abreast and face downward in a reciprocating frame, each set when at the centre of the machine being depressed by a cam mechanism, the other set of blocks being at the same time inked by inking rollers that are driven so as to have the same surface speed as the blocks. The reciprocation of the frame is performed by two cams and a multiplying gear that drives a rack secured to the frame.

In the centre of the machine is a printing table, and beneath it a large drum that moves the fabric at each reciprocation through one-half the pitch of the blocks in the frame. Over this table and round the drum passes an endless apron that is led to rollers on the outside frame, where also is a tightening roller. Outside the apron is an under-cloth, which receives any excess of colour pressed through the drugget during printing; this under-cloth is on a roll at the bottom of the machine controlled by a brake, and after passing with the apron over the table is wound on a similar roll above the end frame. The drugget to be printed is on a roll from which it passes round tension bars and over the printing table; it is then carried by the apron to the end of the frame, where it is separated from the under-cloth and conveyed to a drying screen (not shown), and is finally wound in a finished state on the highest roller of the frame.

1381. Model of rotary printing machine for calico. (Scale 1 : 4.)
Contributed by Messrs. Hoyle & Son, 1857. M. 88.

This is a model of a single-cylinder calico-printing machine, and resembles the four or more cylinder machines now used. The pattern to be printed is engraved on a copper roller, which is inked or coloured by a roller that runs in a bath of colour and has its upper surface in contact with the printing roller; the excess colour is wiped from the revolving printing roller by a fixed steel blade that has a slight longitudinal reciprocation; this blade, called the colour doctor, wipes off all the ink except that in the engraved lines. The calico to be printed is on a roller near the machine, and its delivery is controlled by a friction brake which keeps it tight; it is stretched widthways by passing over two bars, the upper surfaces of which are grooved in opposite directions. The calico then passes under the platen cylinder that presses it upon the printing cylinder, the two cylinders being pressed powerfully together by the lever arrangement in which the bearings are carried. After printing, the calico passes upward and then horizontally over a series of steam-heated chests, then vertically downwards in front of similar chests, then horizontally and vertically through a long course during which the drying is sufficiently completed for the calico to be wound on a roller at the drying end of the machine. The cylinder is continually being wiped on its leaving surface by a second flexible blade, called the lint doctor, which frees it from any fibres deposited by the calico.

An endless felt or blanket passes round the platen cylinder with the calico, and then round beneath the drying chests returning backwards by a circuitous course in which arrangements for taking up the stretch are provided; this blanket forms an elastic cushion for the calico while being printed; it also absorbs and carries away any excess colouring matter.

The application of engraved copper cylinders to the printing of textile fabrics was patented in 1764 by Messrs. Fryer, Greenough, and Newbery; the employment of the steel-strip doctor as here used was patented by Mr. T. Bell in 1783.

1382. Models of rollers for printing calico. (Scale 1:8.)
Presented by J. D. Mucklow, Esq., 1865. M. 981.

These four model cylinders show how the pattern is cut or pressed into the polished copper surface, so that the ink or dye shall remain in the pattern while that on the uncut surface is completely removed by the steel blade or doctor. The calico in passing between the inked cylinder and the platen cylinder is sufficiently forced into the depression to be printed by the ink retained. After printing, the cylinder is wiped by a second flexible blade, called the lint doctor, which removes any fluff left by the calico.

SEWING MACHINES.

Needles of the present shape, but more clumsy and made of bone, were used in prehistoric times. The common steel needle is a comparatively modern invention, and was probably introduced into England in the 16th century; the manufacture has been carried on in the district of Redditch for about 200 years, and during this time the shape has undergone but little change. As in the case with many simple appliances, the work done with it has not been surpassed by machinery, but the skill and attention required are great, and the speed of hand sewing, about 30 stitches per minute, is exceedingly slow when compared with machine work.

In 1775 C. F. Weisenthal patented a needle with a point at each end and the eye in the middle of its length so as to avoid having to turn the needle over when sewing, and such needles pulled and pushed by mechanical pincers have been used in some sewing machines.

In 1790 T. Saint patented a machine (*see* No. 1383) which, if constructed at the time, was the first sewing machine; his drawings embody many of the features that have now become permanent. The stitch is, however, of the single thread or chain type, and two needles are required, one acting as an awl, and the following one, with a notched end, passing the loop through the prepared hole; the machine was intended for leather sewing. In 1830 B. Thimmonier invented and constructed a successful sewing machine, and, with financial assistance from friends, started a factory in which many of these machines were used and their arrangement improved

(*see* No. 1384). His machine did the chain stitch, and used a single-pointed needle with a side notch for the eye. Elias Howe, in 1845, constructed and subsequently patented the first lock-stitch sewing machine, using an eye-pointed needle and an independent shuttle, each threaded (*see* No. 1385). He at once disposed of his English interests to W. F. Thomas, of Cheapside, in whose name the English patent stands. Although Howe was the first man to make a practical success of the lock-stitch sewing machine, he was not the first inventor of the devices that rendered it practicable. In 1832–34 Walter Hunt constructed such a machine with an eye-pointed needle and an oscillating shuttle, and the eye-pointed needle had been patented in England in 1841, but Howe re-invented them, and made the machine a commercial success. In 1849 A. B. Wilson invented the rotary-hook lock-stitch machine, in which the shuttle is reduced to a circular spool round which the needle thread is taken by a revolving hook; examples of this machine are seen in No. 1394. He also introduced the spring presser-foot and cloth plate, now universal, as well as the four-motion feed below the plate that moves the work after every stitch. I. M. Singer, who patented his first machine in 1851, did much to accelerate the commercial introduction of the sewing machine, but till Howe's (or Thomas's) extended patent expired in 1867, royalty had to be paid by all lock-stitch machine makers.

Sewing machines now are made in many modified forms to suit special purposes, but in their action they may be divided into two classes, the chain-stitch and the lock-stitch.

In the chain-stitch or single-thread machine, which was that first invented, the needle passes down through the work to the bottom of its stroke and then lifts a little so as to leave a loop of thread, which by the revolving hook is opened and held while the needle retires. When the needle again enters the fabric in a fresh place it passes through the loop retained by the hook so securing it, while the hook disengages itself and enters the fresh loop, and so on. The high speeds possible with these chain stitchers and the ease with which their work may be undone are great advantages, but for many purposes the sewing is not sufficiently secure, so that domestic machines are not usually of this class.

In the lock-stitch machine the needle, after passing through the fabric and reaching the extremity of its downward stroke, rises a little, then stops, so causing the thread to loop out from the needle. Through this loop a small metal shuttle with one side flat, and having a sharp point, is passed, so leaving its thread through the loop; the needle then lifts completely, and the stitch is drawn tight, there being one thread above the fabric and another below, these crossing each other at the centre if the needle and shuttle tensions are correctly adjusted. As such sewing can only be undone by picking it out a stitch

at a time, the work is very secure. In some lock-stitch machines the shuttle is cylindrical and does not move, the loop from the needle being carried round it by a revolving hook, but the resulting stitch is the same. By giving a variety of motions to the needle or to the work-plate a sewing machine will do such work as herring-boning and ornamental stitching, and the sewing of button-holes is done in this way (*see* Nos. 1411–3).

1383. Saint's sewing machine. Bequeathed by Newton Wilson, Esq., 1894. M. 2688.

This machine was constructed in 1874 by Mr. Wilson from the drawings contained in a patent granted in 1790 to Thomas Saint, cabinet-maker, of London. The specification describes methods of making a kind of artificial leather for use in the manufacture of boots and shoes, but the drawings show and describe three machines which Saint says may be worked by hand or steam power, and be used in making boots and shoes. The first machine is for spinning and doubling thread, the third machine is for plaiting or weaving, while the second, as here represented, he says is for "quilting, stitching, and sewing." It would now be described as a chain-stitch or single-thread sewing machine, and will be found to embody many of the most important features of the modern machines. It is not known if Saint actually constructed such a machine, although the drawings suggest that he did. He probably did not proceed with it, however, as the only subsequent patent in his name was granted in 1802, and is in connection with steam-boilers.

The machine consists of a table with an overhanging arm, as in the present machines, and a horizontal revolving shaft which by cams or tappets reciprocates a vertical needle-bar, traverses or feeds along a box supporting the work, and reciprocates a two-pronged lever and ratchet by which the thread is tightened and the looping performed. The needle-bar contains two tools, the first being an awl and the second a needle, which, instead of an eye, has a simple notch at the lower end, the thread being carried by the notch through the hole already perforated by the awl. The loop so formed below the material was carried along by the ratchet and held for the next loop to be forced through it, and so on, in a way that we now know to be quite easy and satisfactory. The thread in use was contained on the reel on the arm of the machine just as at present.

1384. Thimmonier's sewing machine. Received 1881. Plate VII., No. 2. M. 1527.

This is a copy of a sewing machine used in some patent litigation in America and stated to have been sent to that country from France in 1830.

In 1830 Barthélemy Thimmonier, a tailor of St. Étienne, patented in France a sewing machine resembling this copy, and obtained with it such success that, by 1841, 80 were in use, but a mob then destroyed them all. Thimmonier constructed fresh machines which, it is stated, would make 200 stitches per minute, and this improved type is described and illustrated in his English patent of 1848. One of his machines was shown in the Great Exhibition of 1851, but was unnoticed, and the inventor died in poverty and obscurity in 1857. Although the machine shown has a flywheel driven by a treadle for reciprocating the needle-bar, Thimmonier's patents show the reciprocation obtained directly from the treadle without any flywheel, but whatever the date of the original of this copy, the sewing and knotting mechanism appears to be the same as that of his early machines.

A vertical reciprocating rod carries a horizontal arm from the extremity of which projects downward the needle-bar, and also a presser-foot which is in the form of a nipple that may completely cover the needle. The work to be sewn is supported on a hollow horizontal fixed arm, with a hole above, through which the needle projects downward when at the lower end of its stroke. In this arm is a hook that, by a sliding rack and a pinion, is partly rotated at each stroke, and the thread passes from the reel below to the hook, which wraps it round the needle. The needle is pointed, but also barbed, and having the loop of the thread from the last stitch round it and above the cloth, descends, making a fresh hole, and while below, the thread-carrier winds the lower portion of the thread round the needle which, then rising, draws the lower thread through the upper loop, and so on, thus forming a chain stitch, but one having the loops on the top side. The needle-bar is partly rotated during the upstroke, so as to prevent the barb from catching the upper loop, and it is rotated back again on the downstroke.

The work is fed along by hand between each double stroke, and the presser-foot or nipple holds it down during the upstroke. The return motion of the reciprocating parts is obtained by springs, and the lifting of the presser-foot is done by a catch from the needle arm, but the catch is thrown off automatically when the necessary height has been reached.

1385. Copy of Howe's original sewing machine. Presented by the Howe Machine Co., 1862. Plate VII., No. 3. M. 868.

In this, the first successful lock-stitch sewing machine made by Elias Howe in 1845, the cloth to be sewn hangs vertically and is fixed on pins embedded in the edge of a thin strip of metal (capable of bending easily to the curve of the seam to be sewn) and this metal strip is drawn through the machine by a pinion gearing into it, and so carries the cloth forward in front of the needle.

The needle is curved, and near its point has its eye through which the thread passes from a reel above. The needle is attached to a swinging lever, and when its point has passed some distance through the cloth and is returning, a shuttle which slides in a small trough passes through the loop of thread that extends from the cloth to the eye of the needle, so leaving the shuttle thread in the loop. The needle then withdraws completely and both threads are pulled tight, the needle thread being in front of the cloth and the shuttle thread behind, but both threads cross in each hole made by the needle, as in the case of the modern lock-stitch machines.

The several motions for moving the needle, shuttle, and work, as well as for tightening the thread at each stitch, are given by cams on a shaft that is rotated by a hand wheel. The cloth being sewn hangs vertically, while the needle, though swinging in a vertical plane, passes through the cloth horizontally. The shuttle race is horizontal, the face and point of the shuttle being downwards; the shuttle is thrown from end to end of its travel by blocks jerked by levers, in a similar way to that in which a shuttle is thrown in a loom.

1386. Stitching machine. Contributed by C. Morey, Esq., 1858. M. 347.

This machine was invented in 1849 by Mr. C. Morey, and, although not intended for general sewing, is much used in dyeing and other operations in which calico pieces have to be stitched together in a way that when the work is completed will not present any difficulty in unpicking. The machine consists of two spur wheels on horizontal shafts arranged vertically over each other and geared together. In the middle of the teeth of each wheel a groove is turned as deep as the teeth, and opposite the point of contact of the wheels is a bracket supporting a stout horizontal needle that reaches into the groove; on rotating the spur wheels and placing the ends to be joined between the gearing, the teeth crimp or fold the cloth, forcing it

forward in this condition and so driving it on to the fixed needle. When the fabric is through, it and the needle are removed from the machine and the needle is used to pull through the thread for the stitching.

1387. Judkins's sewing machine. Lent by Messrs. Platt Brothers & Co., 1894. M. 2562.

This machine, which was made at Messrs. Platt's works, was shown at the 1851 Exhibition by Mr. C. F. Judkins, and, it is stated, worked at the rate of 500 stitches per minute. The work is placed against a vertical table and the needle moves to and fro horizontally. It is a lock-stitch machine and the shuttle, which is always visible, is held in a carrier working in guides at the front of the machine. The presser-foot takes the form of a flat steel spring, but also contains a toothed roller, free to revolve but held by flat springs that press it on to the work. The feeding is performed by a roughened disc behind the work that receives intermittent motion from the internal mechanism. Within the cast-iron box that forms the frame of the machine is placed a large cylindrical cam, which can be driven by a hand wheel or by belt pulleys arranged outside. A stud, projecting downward from the needle-bar, engages in a double groove in the cam, the needle making two stitches for one revolution of the shaft. Parallel with this shaft is another driven by gearing at twice the speed. The second shaft by an overhanging crank and connecting rod reciprocates the shuttle-carrier, and by an eccentric drives a pawl fitting into a ratchet wheel on the feed shaft, on which is a pinion gearing into teeth on the feed disc.

1388. Lock-stitch sewing machine. Presented by Mrs. S. E. McCulloch, 1898. Plate VII., No. 5. M. 3014.

This is an early example of the Howe machine made by Messrs. W. F. Thomas & Co., of Cheapside, who had purchased the British rights in Howe's invention. The machine shown is No. 1231 and is in accordance with Mr. Thomas's patent of 1853.

The needle-bar is reciprocated in vertical guides by a lever actuated by a cam groove on the flywheel disc and the shuttle-carrier is reciprocated in its long horizontal guide by a similar cam. The feed is given by the presser-foot, which receives a scuffing motion from a pair of cams on the flywheel shaft. The thread tension is adjusted by a strap brake acting on the spindle to which the reel is secured. The fly-wheel shaft is at right angles to the operator, and this arrangement caused the use of a peculiar form of treadle motion in which the treadle bar resembles an inverted T. The shuttle bobbins were filled by the independent winder shown, which was attached to the table; the work table of the machine was formed by the small upper board.

1389. Lock-stitch sewing machine. Made by Messrs. W. F. Thomas & Co. Received 1883. M. 1673.

This machine closely resembles the construction patented by Mr. Thomas in 1853. The overhanging arm and vertical sliding needle-bar are employed as at present, but the motions for the needle and the shuttle-holder are derived from cams in the face of the main driving wheel. The feeding is also derived from a cam motion but is performed by the presser-foot.

1390. Original Singer sewing machine. Presented by the Singer Manufacturing Co., 1892. Plate VII., No. 6. M. 2456.

This is one of the first Singer sewing machines and, though constructed in 1854, is still in working order. It is a lock-stitch machine, and the shuttle, which is of the elongated form, is worked transversely by a carrier having on its side a V-shaped slot in which moves a crank pin attached to the underneath shaft. The needle motion is obtained from a

crank pin on the upper shaft working in a V-shaped slot in the needle bar. The needle thread tension is adjusted by altering the extent to which the thread is coiled round a smooth wire, and the thread is held at the commencement of the downstroke by an additional tension put on by a cam at the back of the crank plate. The feed is of the wheel type, the feed wheel being moved intermittently by a band, worked by a rocking lever from a cam on the underneath shaft, a wooden brake block giving sufficient friction to prevent the backward motion of the feed wheel during the return of the band.

1391. Sewing machine. Contributed by W. F. Thomas, Esq., 1858. M. 349.

The special features of this machine were patented by Mr. Thomas in 1855, but in its general arrangement it resembles No. 1389. The feeding is done by the presser-foot, but to vary the direction of feed so as to give a curved seam, the foot is carried in a cylindrical guide within which it can be turned. In modern machines this result is generally obtained by turning the work. An independent driving arrangement is added for winding the shuttle bobbins.

1392. Early sewing machine. Lent by Lawson Tait, Esq., F.R.C.S., 1892. M. 2495.

This roughly constructed machine is said to have been made during the first half of the last century by Charles Kyte, a native of Snowshill, near Evesham. It is uncertain whether Kyte invented or simply copied the important features in this machine.

A four-legged wooden stool supports the table on which the machine is carried. The treadle acts upon a cranked axle carrying a wooden flywheel which is weighted near the circumference by lead run into auger holes. A small pulley on the spindle of the machine is driven by a belt from another pulley on the flywheel, and a crank in the spindle communicates a vertical reciprocating motion to the needle-bar by means of a long rocking lever. A steel ring, fixed eccentrically to the side of the upper pulley, acts as a cam and gives motion to a long arm which works the shuttle carrier. On the other side of the crank which works the needle-bar is a small cam giving a side motion to a horizontal rocking lever which feeds forward the work. The light flat spring on the table fitted with a small pulley appears to have been a tension arrangement. The needle and shuttle are missing and their form is unknown.

1393. Lock-stitch sewing machine. Presented by the Florence Sewing Machine Co., 1867. M. 1038.

This is an early form of machine, and has a very low arm carrying the presser-foot, while the needle, which is curved, is carried on a separate rocking arm and, being directly driven by a crank, has not a preliminary upward loop-forming motion. There is the usual toothed feeding surface projecting through the work-plate, and it receives its motion from a crank; but the direction of feed is immediately reversible, the fulcrum of the feed lever being movable in a slot in the lever, by which arrangement also the rate of feed is varied; this adjustment is made by a milled head at the side of the table.

1394. Lock-stitch sewing machine. Presented by A. C. Hyde Parker, Esq., 1904. M. 3315.

Another contributed by Messrs. Newton Wilson & Co., 1868. M. 1111.

The earlier of these machines, shown with its work-table removed, was made by the Howe Sewing Machine Co. about 1867, while the other specimen is a slightly improved copy of it. In each machine the power is

transmitted from a treadle wheel below (not shown), by a belt running over a small pulley on a horizontal shaft beneath the work-table, there being no spur gearing.

At one end of this driving pulley is an eccentric which actuates a rod connected with an arm capable of being oscillated between centres and provided with an extension piece that serves as a needle-bar; the needle is, consequently, of the curved variety, and there is no special loop-forming movement. The shuttle is of the cylindrical or disc type introduced by Mr. A. B. Wilson, and is carried in a revolving holder provided with a hook by which the loop in the needle thread is carried round the shuttle so as to be locked by the lower thread; there is a brush in contact with the revolving hook, to check the thread while being carried round. The shuttle hook is on the shaft of the driven pulley, and near it the flange of this pulley is so shaped as to form two cams, one of which gives the vertical movements to the feed bar while the other causes the horizontal reciprocations required to complete the motion; the return portion of the horizontal reciprocation is given by a spring, and there is a cam beneath the table by which the length of stitch can be adjusted. The tail end of the revolving shaft serves as a shuttle-winder, and the shuttle is removable by withdrawing a circular bracket that is retained by a clamping screw. In the later machine this bracket is carried on a swinging arm fitted with a spring, and the presser-foot is provided with a transparent glass plate.

1395. Lock-stitch sewing machine. Contributed by Messrs. Newton Wilson & Co., 1868. M. 1110.

In this machine the needle-bar moves vertically in a long guide and is driven by a bell-crank that receives its motion from a cam on a horizontal belt-driven shaft below. A similar cam and bell-crank lever, arranged beneath the table, move the shuttle-holder backwards and forwards in a straight horizontal race, while a four-motion feed is given by a toothed lever operated by two small cams on the main shaft.

1396. Lock-stitch sewing machine. Contributed by Messrs. Newton Wilson & Co., 1868. M. 1112.

In this machine a hand wheel provided with internal teeth drives two horizontal shafts arranged above and below, each shaft being fitted with a pinion. The upper shaft oscillates the vertical sliding needle-bar by a crank-pin working in a straight transverse groove. The lower shaft extends below the table and terminates in a revolving hook that incloses a circular shuttle; a cam on this shaft gives the usual feed motion.

1397. Chain-stitch sewing machine. Contributed by Messrs. Newton Wilson & Co., 1868. M. 1109.

This machine has a rocking needle-bar and a curved needle. It is driven by a belt on a shaft below the table and almost directly under the needle, so that the complete needle-bar is of a U shape. The needle motion is given by a crank-pin working in a straight slot in the needle-bar, and the looping hook is on the top of a vertical shaft that has a quick-pitched screw upon it, into which engages a nut fixed to the lower end of the needle-bar.

1398. Chain-stitch sewing machine. Contributed by Messrs. Newton Wilson & Co., 1868. M. 1113.

This is arranged very similarly to the lock-stitch machine, No. 1396. The lower shaft, however, terminates in a revolving hook that retains the loop of the preceding thread till it is engaged by the next one, in the usual manner of s.ngle-thread machines.

1399. Lock-stitch sewing machine. Received 1881. M. 1526.

This represents the original form of lock-stitch machine manufactured by the Remington Co., and appears to have been made about 1867.

The needle-bar is reciprocated by a cam-groove in a face plate on the horizontal driving shaft, which is provided with a flywheel and arranged for belt driving, By a crank, this shaft rocks a shaft below the table, and this moves the shuttle-holder and the feeding arrangement. The feed is given by a serrated wheel, just showing above the level of the table, and actuated by a lever and friction pawl very similar to the silent feed of a saw frame.

1400. Lock-stitch sewing machine. Made by the Howe Machine Co., 1871. M. 1236.

The needle-bar is carried in vertical guides, and is oscillated by a bell-crank that receives its motion from a cam on the main driving shaft below. A similar cam and bell-crank oscillate the shuttle-holder in a straight horizontal race, while a double cam gives a four-motion feed.

1401. Lock-stitch sewing machine. Made by the Howe Machine Co., 1888. M. 1942.

This represents the final form of machine manufactured by the Howe Co. The arm is high, and contains a horizontal driving shaft, which by a crank-pin and V slot gives motion to the needle-bar that works in vertical guides. The shuttle works in a curved horizontal race beneath the table; it is oscillated by a lever turning on a centre below and driven by a vertical lever swinging on a centre some way up the standard. This vertical lever is oscillated by a crank on the main shaft, a similar crank and lever working the feed motion. For winding the shuttle bobbins uniformly, a spring plate is fitted that presses the thread being wound on the bobbin close to the preceding coil; the thread is supplied from a swinging arm above that gives it a straight lead.

1402. Lock-stitch machine. Lent by the Singer Manufacturing Co., 1888. M. 1961.

This is described as a family machine and is arranged for driving by hand or treadle.

On the horizontal shaft is an overhanging crank-pin that by a connecting rod reciprocates the needle-bar, while an adjacent cam rocks a lever that forms the thread-tightener. The shuttle is in the form of an oscillating hook containing a short cylindrical bobbin; the hook passes through the loop of the needle thread, carries it round the shuttle and then releases it, so virtually passing the shuttle and its thread through the loop of the needle thread. The oscillation of the shuttle is performed by a horizontal rocking shaft, driven by an arm on a parallel shaft that is rocked by a connecting rod from a crank on the upper shaft. The feed is of the four-motion type and is driven by two horizontal rocking shafts beneath the table; one of these is rocked from the shuttle motion and the other from a cam on the upper shaft which rocks a lever having its fulcrum within the vertical standard. This fulcrum is carried on a rocking lever by which its position can be altered from the front of the standard, and so the length of stitch may be varied. A shuttle-winder is driven by friction from the rim of the flywheel, and beneath the machine is an inclined mirror by which the shuttle and feed motions are rendered visible.

1403. Lock-stitch sewing machine. Lent by the Wheeler & Wilson Manufacturing Co., 1888. M. 1955.

This is a treadle-driven machine with the driving belt passing over a pulley on a shaft, contained in the horizontal arm of the main bracket; the needle-bar reciprocates in vertical guides. From a crank on this shaft a slotted connecting rod passes downward and slides on a stationary block;

the prolongation of the connecting rod is fitted with a pin that slides in a slotted crank arm on the extremity of a horizontal shaft, extending below the base of the machine. In this way continuous rotary motion is transmitted from the upper to the lower shaft without the use of gearing, but with the required variation in the velocity necessary to give time for the passage of the shuttle. At the extremity of the lower shaft is a revolving hook, which encloses a cylindrical shuttle; when the needle is down the point of the revolving hook passes between the needle and the thread, so opening the loop, carrying it round the shuttle and then releasing it, the result being that the shuttle with its thread passes through the loop between the needle and its thread. The four-motion feed is driven from a cam on the lower shaft.

1404. Lock-stitch sewing machine. Lent by the Wheeler & Wilson Manufacturing Co., 1888. M. 1956.

This machine is similar to No. 1403, but the communication of the motion from the upper shaft to the lower one is by two cranks at right angles on each shaft and coupling rods, a uniform motion being transmitted, but at the extremity of the lower shaft is a crank pin which, by a short connecting rod, transmits to a crank on the shuttle-hook shaft a rotary motion with the desired variation in velocity. The feed is derived from two cams on the lower rotating shaft and is very pronounced; it is adjusted by a lever near the hand wheel.

1405. Moldacot sewing machine. Presented by T. A. Bowler, Esq., 1897. M. 3001.

This portable lock-stitch sewing machine was patented by Mr. S. A. Rosenthal in 1885, but improved and manufactured by the Moldacot Pocket Sewing Machine Co. in 1886–7.

The machine is provided with a cramp for securing it to a table, and, when fixed, is worked by vertically reciprocating the needle-bar, to which, however, the upward movement is given by a spring; in the later form shown, an eccentric and winch handle were introduced for driving, but without any multiplying gear. The shuttle is carried in a segmental holder, which receives a swinging motion owing to a pin on the lower end of the needle-bar engaging with a curved slot in the carrier. The presser-foot is held in an arm forced down by a spring, and rocked by a projection on the needle-bar at each extremity of the stroke; there is, however, an adjustment provided by which the length of the stitch can be varied. The loop-tightener is directly worked by a pin on the needle-bar, but the needle, from its lowest position rises continuously, leaving a loop behind it without resorting to the usual intermittent loop-forming motion. The tension of the needle thread is regulated by friction plates.

1406. Jacquard sewing machine. Lent by the Singer Manufacturing Co., 1888. M. 1962.

This is a multiple machine with four independent needles and shuttles at work at the same time; it is designed for sewing the successive pattern cards of a Jacquard loom on to continuous tapes or cords with great exactness, so that they shall all be parallel and at a uniform pitch. The cards are placed on pegs on the rim of a skeleton drum and by the machine are sewn to four tapes above the cards and four tapes below them; each tape supply is contained on a separate bobbin. The secured cards are carried round by the drum, and then leave it as a continuous pattern chain. All parts are adjustable sideways so that cards of various widths can be dealt with.

The power is received by a shaft near the floor which transmits motion to a rocking shaft that reciprocates the needles, and to four racks that partially rotate four shuttle hooks, which carry the loops of the needle threads round the circular shuttles. The feeding of the cards under the needles is done by the motion of the skeleton drum, which is slowly rotated by a ratchet feed from the main shaft.

1407. Twin-needle sewing machine. Lent by the Wheeler & Wilson Manufacturing Co., 1891. M. 2335.

In this machine two needles and threads are carried by a single needle-bar, while a shuttle below passes its thread through both loops, so that two parallel seams, connected by the lower thread, can be simultaneously sewn, In addition, the needle-bar is carried in a swinging guide, oscillated in a direction perpendicular to the feed by a rod fixed in a rocking quadrant on the machine arm and driven by a cam on the driving shaft. By this device the threads can be made to follow a zig-zag course, which is adjustable by altering the rate of feed or the swing of the needle-bar guide. A single needle may be used, and then with the zig-zag motion thrown out of gear, the machine does the ordinary stitch for general work, the fancy stitching being chiefly employed on leather.

1408. Boot-sewing machine. Lent by W. H. Beck, Esq., 1885. M. 1635.

This is an experimental model of a machine for sewing boots, patented in 1869 by Mons. A. Destouy, and in an improved form by Mr. Beck in 1876. Its construction is interesting, as a loose needle is used, which is pulled and forced through the material in a way that resembles hand sewing.

The needle is in the form of a ring with a portion of its circumference removed, one extremity is pointed and the other hooked so as to form an eye. This needle is revolved intermittently in a circular path and so sews through the work; the thread does not, however, remain all the time in the eye, but during a portion of the stitch is held by an auxiliary finger. The step-by-step rotary motion is given to the needle by pincers, formed by two nipping levers arranged on opposite sides of the main centre and rocked by cranks on an upper shaft. The thread used passes through a hot-water-jacketed chamber to soften it.

1409. Lock-stitch sewing machine. Made by the Howe Machine Co., 1888. M. 1940.

This is a lock-stitch machine for sewing leather and other heavy work. There is a single rotating shaft arranged beneath the bed and driven by a belt. A cam on this shaft rocks a bell-crank lever that reciprocates the needle-bar, which slides in vertical guides; a second cam and bell-crank lever reciprocate the shuttle-holder, which runs in a straight horizontal race. At the end of the shaft is a steel cam of conical shape, adjusted in position along the shaft by a nut having a milled head. This cam actuates a lever which forms part of a nipping lever or silent pawl, that intermittently rotates a steel disc with serrated edge, the top of which projects through a slot on the work table. The work is held down on this feeding arrangement by a loose wheel carried on the presser-foot. There is a shuttle bobbin winder very similar to that on No. 1401.

1410. Lock-stitch sewing machine. Made by the Howe Machine Co., 1888. M. 1941.

This is a heavy sewing machine particularly designed for shoemakers' use, but it is provided with a removable table for use on ordinary flat work. The needle is reciprocated by a lever driven by a cam in the face of the main driving wheel; another cam in this wheel moves horizontally a rod that terminates in a rack, gearing into a small pinion with its axis vertical, arranged beneath the table. This pinion turns to and fro a revolving hook enclosing a circular shuttle which, by the hook, is enabled to pass its thread through the loop formed in the needle thread. The small size of the lower arm enables the machine to work on portions of a boot that would otherwise be inaccessible. A cam on the main shaft vibrates a lever that gives a vertical motion to the presser-foot, and a similar cam and lever give a

horizontal motion to this feed, so that the feed is given by the foot itself. The presser-foot and needle-bar are contained in a cylindrical plug which can be turned within the sleeve holding it to the main casting, so that the direction of the feed can be continually changed without altering the position of the work. Some spare shuttle bobbins and a multiplying gear for winding them are also shown.

1411. Button-hole sewing machine. Contributed by Messrs. Newton Wilson & Co., 1868. M. 1108.

This is an early button-hole machine, manufactured in America in 1868. Beneath the table is a horizontal belt-driven shaft on which are three cams and a crank; one cam rocks a bell-crank lever that reciprocates the needle-bar in its vertical guides, another oscillates a shorter arm beneath the table and rocks a curved needle, while the third cam controls a swinging hook also beneath the table, and which acts as the hook in a chain-stitch machine. The crank works a four-motion feed, while a helical sleeve encircling the upper needle-bar carries a hook that acts as a looper for the thread of the lower needle. In this way two chain-stitch machines are combined in one, and both sew round the cut button-hole.

1412. Button-hole sewing machine. Lent by the Singer Manufacturing Co., 1888. M. 1964.

In this machine the button-hole is cut by a die attached to a hammer, then the hole is sewn round by a needle, the motion of the work at the time being controlled by an external cam plate that agrees with the shape of the hole. There is a thick filling thread below and a thinner sewing thread which is interlocked with the needle thread, these two threads sewing over the cut edges and at the same time enclosing the filling thread. An inclined mirror is arranged that renders the lower mechanism visible.

1413. Button-hole sewing machine. Lent by the Wheeler & Wilson Manufacturing Co., 1891. M. 2336.

This is a machine for sewing round the edges of the material where a button-hole is required, and then cutting the hole. The work is placed on a movable plate and secured to it by a small rectangularly slotted frame, which covers the intended position for the button-hole and is held down by a spring. The needle and shuttle movements are the same as in the ordinary sewing machine of this type, but the feed motion given to the plate is quite different. The plate, carrying with it the work, receives three separate motions: a quick vibratory one at right angles to the hole to make the stitches, one along the length of the hole, and a third to move the work across when one side of the hole is completed so that the other side may be stitched. When the two connected rows of stitches have thus been inserted, a knife moves rapidly down and cuts the enclosed cloth, so completing the button-hole.

The special movements of the plate are obtained from a switch cam, secured to the main shaft beneath the table. This cam directly gives the vibratory motion to the plate, and the feed is derived from a lever driven by the cam and moving a pawl over a ratchet wheel on the top of a turntable. A block which works in the switch cam is held by a helical spring on each side, so that when the stitching of one side is finished one spring has been compressed sufficiently to force the block, against the action of the other spring, into another groove in the cam, so that the work then returns and the other row of stitching is done. The knife-bar is forced down by springs which are released when the turntable has completed a revolution, a projecting pin upon it catching a lever connected with these springs.

All the movements, including the cutting, take place automatically when the work has been adjusted in the proper place, and it is stated that six button-holes a minute can be sewn with this machine.

1414. Lock-stitch sewing machine. Presented by the Singer Manufacturing Co., 1897. M. 2982.

This is a domestic machine intended for treadle-driving, but it has been sectioned and supported on a special stand with a mirror below, to show the means whereby the various movements are obtained without the employment of toothed gearing.

The horizontal driving shaft is in the arm, and has an overhanging crank-shaft which, by an edge cam, reciprocates the needle-bar, while an adjoining face cam rocks the thread-tightening lever. Another crank on the driving shaft rocks an upright shaft, carried between coned adjustable screws, which gives motion by means of a connecting rod to a bell crank connected with a light shuttle-carrier which thus receives an oscillating or "vibrating" movement; in this way the shuttle is swung through the loop of the needle thread, which thus slips round the shuttle before again being tightened. The feed is of the four-motion type, and has the vertical component given by a swash-plate attached to the shuttle-carrier, while the horizontal movement is obtained from a shaft below the base, rocked from an edge cam on the driving shaft which oscillates a lever having its fulcrum in a slotted lever within the vertical standard; the position and angle of the slot can be so varied by a thumbscrew as to give any required length of stitch.

The bobbin winder is driven by the main driving band, and the thread is automatically distributed over the bobbin by a guide moved by a cam driven by worm gear.

1415. Shuttles for sewing machines. Presented by the Singer Manufacturing Co., 1897. M. 2983.

A is a shuttle for a family machine; it has the bobbin inserted through the side, and the tension adjusted by threading the cotton through certain of the five holes provided.

B is for a family machine; it is oscillated horizontally in a curved path, and has the bobbin inserted through the end so as to be completely protected. The tension is given by side springs under which the cotton is passed without threading.

C is a vertically oscillating hook-shuttle used in domestic machines, and also in those for factories where they are driven at from 1,500 to 1,800 stitches per minute. The bobbin is of the short cylinder type, and the hook and guides loop the needle thread round it, which is equivalent to passing the bobbin through the loop of the needle thread.

D is an oscillating hook-shuttle, intended for speeds of from 2,000 to 3,000 stitches per minute; to reduce the momentum the hook only is oscillated.

E is an oscillating hook-shuttle with a large bobbin, the axis of which is in the plane of the hook; it is used in heavy textile and leather work.

F is a small horizontally oscillating shuttle, which can be used in a small work-supporting arm. This arm will reach into difficult positions, such as the interior of a child's boot, so that stitching can be done close to the toe of the boot.

G is one of the three or four large oscillating shuttles used in a machine for lacing together the pattern cards of a Jacquard loom; from 1,000 to 3,000 of these cards are frequently sewn together to form a continuous pattern chain in a machine resembling No. 1406, but dispensing with the use of tapes. Both the shuttle and needle threads are in the form of braid which is found to be a sufficient connection; the needles do not, however, pierce the holes through which they pass.

1416. Lock-stitch sewing machine. Lent by the Singer Sewing Machine Co., Ltd., 1908. M. 3554.

This is the latest domestic sewing machine made by the Singer Co., and is an improved form of No. 1414. It is a lock-stitch machine, and the stitches are formed by means of a hook, which oscillates below the work

plate about a vertical axis, and carries the loops of the upper thread around a stationary bobbin containing the under thread. The needle-bar is actuated by a crank and connecting rod, and, consequently, moves up and down without any intermittent loop-forming motion, while, owing to its not being continued through the top of the machine, the bar is shorter than usual. The take-up mechanism is operated from the same crank as the needle-bar, and the four-motion feed is similar in general features to that employed in the earlier example. An arrangement is provided whereby, when the presser-foot is raised, the upper thread is released from its tension, and, when the under thread bobbin needs refilling, it is readily removed from its casing by means of a push piece and a lever.

The example has been sectioned and mounted upon a stand with a mirror below to render visible all the mechanism employed.

1417. Chain-stitch sewing machine. Lent by the Willcox & Gibbs Sewing Machine Co., 1906. M. 1930.

This is the modern form of the single-thread sewing machine patented by Mr. J. E. A. Gibbs in 1857, and subsequently improved by Mr. J. Willcox.

The machine is driven by a hand wheel connected by a cord with a pulley on a horizontal shaft below. At the end of the latter, just below the work plate, is secured a revolving hook or looper which is so designed that each loop is twisted through half a turn after it has been drawn through the preceding loop, a more secure chain being thus obtained. The needle bar moves vertically in bearings, and receives its motion from an S-shaped lever which is connected with an eccentric on the driving shaft below, while the take-up device, for pulling the thread tight after each stitch, consists of a small slotted piece which is secured to the top of the needle-bar and embraces a fixed elongated metallic loop through which the thread passes. A spring tongue forming part of the loop detains the thread when the needle is descending until the eye of the latter enters the fabric.

In place of an ordinary friction-tension device, an intermittent thread clamp is employed consisting of an arrangement of discs and rings between which the thread is passed. The discs are forced together by a spring, securely gripping the thread, except during a short portion of each stitch, when the thread is released by the action of a second eccentric on the driving shaft. This release is timed to occur when the needle-bar is near the extremity of its upward stroke and after the stitch has been tightened by the rise of the take-up. The thread is then held in slight tension owing to the weight of a ring above it, but it will run if pulled, and the amount required for the next stitch is drawn off before the thread is again clamped. The thread reel is mounted upon an inclined pin and is supported by a disc which has an annular flange overhanging the reel. As the axis of the pin points to the first eyelet hole of the threadways, the thread is unwound without causing the reel to revolve in the usual manner.

The cloth-feeding surface is supplied with three sets of teeth, and receives four motions in each stitch. It is first pushed up into the cloth and then moved forward through the required amount of feed, carrying the cloth with it. Afterwards it descends below the level of the work plate and finally returns to its initial position. These motions are derived from a cam, placed on the shaft near the looper, which gives a horizontal motion to a rocking lever in addition to imparting an up-and-down motion to a sliding feed bar upon which the teeth are mounted. The rocking lever engages with a projection from a link, one end of which is hinged to the feed bar, while the other terminates in a curved slot engaging with a pin mounted on a stitch-regulating piece. The horizontal feed motion thus imparted to the feed bar depends upon the distance between the projecting piece and the fulcrum of the rocking lever, which distance can be varied by rotating the stitch regulator and thus altering the inclination of the link. The feed bar

is provided with a spring to give the return motions, and the number of stitches per inch corresponding to the position of the stitch regulator is indicated through a hole in the work plate.

1418. High-speed lock-stitch sewing machine. Lent by the Willcox & Gibbs Sewing Machine Co., 1906. M. 1931.

This high-speed machine, capable of making 4,000 stitches per minute, embodies improvements patented by Messrs. Willcox & Gibbs in 1886–98. It is a lock-stitch machine of the rotating hook type with a rotary take-up.

The driving shaft revolves within a horizontal arm, and actuates the needle-bar by means of a crank and connecting rod. To reduce to a minimum the vibration caused by the rapidly reciprocating bar, the crank is counterbalanced, while the top of the bar fits into an enclosed air space which acts as a dash-pot.

The rotary take-up is mounted on the extremity of the shaft, and consists of two circular plates between which the thread passes. The plates are held together by two studs, and the arrangements are such that the thread is drawn tight at the proper time after each stitch by the outer stud, which is eccentric to its bearings in the plates, and has a slotted head whereby it can be rotated. Its distance from the centre of the plates can consequently be varied, and the necessary adjustments for different thicknesses of work are thus obtained.

The rotating hook is secured to the end of a second shaft, beneath the work plate, and has a cup-shaped recess into which the under-thread bobbin-case fits. This shaft is driven from the main one by means of pulleys and belting at a speed ratio of three to one, the hook performing two idle revolutions each stitch to allow time for the action of the rotary take-up. To ensure the correct timing of the various actions the pulleys are provided with equally spaced pins which engage with perforations in the belt.

The four-motion feed is actuated by two eccentrics on the main shaft, one producing the vertical and the other the horizontal movements. These eccentrics are situated in the pillar of the machine and are connected with the feed bar by means of rocking shafts below the level of the work plate. Variations in the length of stitch are obtained by employing an eccentric having an adjustable throw to produce the horizontal feed. In this eccentric the shaft passes through a hole which is big enough to allow lateral movements. Pins, secured to a flange on the shaft, engage with radial slots in an extension of the eccentric, whilst another pin, mounted on the latter, fits into a cam-groove in a disc which can be rotated relatively to the shaft. Such rotation causes a radial displacement of the eccentric and consequently varies its throw. When making this adjustment the disc is locked by means of a stop-pin engaging with a notch, and the shaft is then rotated by hand until the required number of stitches per inch is indicated. Flexible steel plates are employed to connect the reciprocating parts of the feed mechanism.

As the upper thread pull-off is actuated by the adjustable eccentric, the slack thread drawn from the reel varies with the length of stitch.

1419. Overlock seamer. Lent by the Willcox & Gibbs Sewing Machine Co., 1906. M. 1932.

This machine, patented by the makers in 1892, unites two pieces of fabric at their edges by means of a double-thread over-edge seam and also removes the superfluous material; it is especially suitable for making up garments of hosiery web.

The upper thread is carried into the work by a needle in the ordinary manner, while the second thread, which is preferably a single-ply yarn similar to that of which the fabric is knitted, passes through a hole near the end of the lower member of a double-jawed looper which is made to follow a path in the shape of a **U** with the limbs horizontal, passing under and over the work round its edge. The upper jaw takes the form of a hook

which, near the extremity of the under stroke, seizes a loop of the upper thread, formed below the work when the needle begins to rise, and carries it round the edge of the work until it slips off the the hook and is caught by the lower jaw, which in advancing over the work carries a loop of the second thread through the seized loop. When the looper is at the extremity of its over stroke the needle descends, and its point passing through the second-thread loop carries a loop of the upper thread with it. In this way successive loops of the two threads are made to interlock at places where the needle enters the fabric and at the edge of the work, and form what is named an overlock seam in which the raw edges of the fabric are covered. The needle, which is curved and mounted on a swinging arm, enters the work obliquely in order that the looper may move in a vertical plane and yet pass on different sides of the needle during the under and over strokes. An arrangement consisting of a pair of knives, the upper of which moves up and down each stitch, trims off the superfluous material at the edge and, as the distance between the knives and the needle is adjustable, variations in the width of the seam can be obtained when necessary.

Separate take-up mechanisms are provided for the two threads, and modified forms of friction-tension devices are employed in which the washers are rotated by the threads and thereby kept free from the lint shed by the yarn. There are two feed surfaces, one acting on the work in front of the needle and the other in the rear. The latter feeds slower than the former with the object of preventing any stretching of the material.

The various motions are derived from a driving shaft below fitted with eccentrics and cams, together with rocking shafts carrying swinging arms. The U-shaped movement of the looper is obtained by means of two oscillating cranks which are connected by a link having an extension, on the extremity of which the looper is mounted.

ROPE-MAKING MACHINERY.

Hemp has been employed for the manufacture of rope and canvas from a very remote period, its use being mentioned B.C. 450. In the manufacture of rope, the earlier stages by which the hemp is prepared and its fibres straightened out do not possess any general interest, the process chiefly consisting in a prolonged soaking in water and a subsequent drying, breaking, and heckling.

In making the hemp into rope, the coarseness of the fibres and their great length, about 3 ft., have rendered the advantages of machine over hand work less pronounced than in many industries, so that hemp is still extensively spun by hand, assisted only by the very primitive machines of a rope-walk. The spinner wraps a quantity of prepared hemp round his waist, and then pulling forward a tuft, twists it and attaches it to a hook at one end of the walk. This hook, or whirl, is rapidly rotated through multiplying wheels by an assistant, so twisting the fibres into a yarn, while the spinner walking backwards continues to feed more fibres, end on, into the yarn, until he reaches the limit of the walk, sometimes 400 yds. After some minor operations, the completion of the rope is

proceeded with by combining three or more of these yarns into a single cord in such a way that there shall be no tendency for the rope to untwist. This process, known as laying, is of great interest, and in a rope-walk is performed by attaching the three strands at one end to a single hook on a carriage at one end of the walk, and the other end of each yarn to separate hooks at the other end of the walk. The three yarns are at first consolidated by twisting each separately, and then the three strands are twisted into a single rope by the revolution of the single hook on the carriage, which slides up as the twisting reduces the length. When the strands are twisting together, their individual hooks are being revolved at the same rate as the main single hook, so that the twist of the fibres of the strands is not altered by the laying twist. A conical plug of wood with three grooves in it, called a lay-top, is squeezed along the three strands as they close together, and by its presence secures uniformity in the strand.

The first important machine for laying a rope was the cordelier, patented in 1792 by the Rev. E. Cartwright; in 1805 Capt. J. Huddart improved it and introduced it with other machinery into Chatham Dockyard, where he made great advances in the manufacture of hemp ropes and cables. In Cartwright's laying machine three bobbins of twisted yarn were attached to a revolving disc, but through epicyclic gearing the bobbins, although going round in circles, do not rotate on their axes, the top of the bobbin remaining uppermost right through the revolution. The three strands laid together by this arrangement do not have their individual twisting altered, but are simply formed into a twisted rope that itself strongly resists untwisting. Instead of the axis of the machine being horizontal it may be arranged vertically (*see* Nos. 1421–2).

Another modification is to arrange the machine horizontally with the bobbin-holders in line along the axis where their rotation can be prevented by gravity. The strands are led along the revolving frame to a common lay-top; this machine runs at a high speed owing to all the weights being so near the axis, and the bobbins not revolving except to unwind.

To place all the bobbins of yarn in a stationary frame or creel and strand them together while winding on to a revolving drum is a very simple way of arranging the parts (*see* No. 1420), but it does not offer such facilities for inspecting the work in progress as does the moving bobbin system and the length of rope that can be formed is limited.

In laying hemp rope the correcting motion of the bobbins rather exceeds that of the lay-top, the excess twisting, or "forehard," so given forming a firmer rope. For wire rope, which is made in similar machines, forehard is not required, as this would only be twisting the individual wires, and so weakening them. Rope made of wire was first used for mining in 1831; for rigging and general hauling its use has

greatly extended, while for lifting purposes it has now, to a considerable extent, displaced chain.

Another method of forming a rope is by plaiting, but it is much less convenient than stranding, and such ropes cannot be spliced. They have, however, the great advantage that stretching does not tend to twist them, so that a suspended load does not spin. For covering other cords, and even whips, similar plaiting is resorted to. The bobbins containing the strands are mounted vertically and, under the guidance of cam grooves on a lower plate, describe the zig-zag courses necessary for plaiting. Similar machines are used for plaiting candle wick, but a later form of machine for this purpose is seen in No. 1424.

1420. Rope-making machine. Presented by H. Cotton, Esq., 1874. M. 1764.

This is a machine for laying together as many as 49 strands to form a cotton rope such as is used for driving purposes. The separate bobbins holding the material to be stranded are contained in a stationary creel, from which the strands pass through an eye to the twisting and winding-up machinery. This consists of an open frame that can be rotated round a horizontal axis, while through a hollow trunnion at one end the strands enter twisted together into a rope. This rope passes round two friction sheaves, driven at constant speed, and on to a winding drum, which is driven by a friction coupling so that as the drum fills increased slipping can take place to allow for the enlarged diameter; the rope is led on to the drum by a fork moved by a cam. The mechanism is all driven by a stationary spur-wheel gearing into a wheel attached to the revolving frame.

This machine does not strand in the ordinary way, and to lay a rope that shall not unwind it requires that a definite excess of twist shall be given to the yarn of the individual strands to correct the untwisting done in the machine; stationary creel machines require each bobbin to be mounted in an epicyclic frame if general work is to be done.

1421. Wire rope machine. Contributed by W. Smith, Esq., 1872. M. 1265.

This machine, patented by Mr. Andrew Smith in 1849, differs from the earlier machine of Cartwright in that the epicyclic motion of the bobbins is obtained by linkwork instead of gearing, also that it is arranged vertically.

It consists of a frame having below a disc-wheel, that is driven by bevel gear from a horizontal shaft. Above this disc is attached a revolving cage that carries six bobbins supported in separate frames; above the cage is a seventh bobbin which carries the material for the core of the rope. The cage is not concentric with the lower disc, and the carriers of its bobbins are each provided with a crank arm which fits on a separate pin on the lower disc, so that as the disc is driven these arms pull round the cage, but at the same time prevent the rotation of the bobbin frames, the arrangement being a "parallel-crank" chain. From the bobbins the wires pass over guide sheaves to a lay-top above, then, after being stranded together, over a return sheave they pass to a winding-off sheave below, and are finally wound as a finished rope, on a drum which is driven by a slipping belt so as to be independent of the variation of diameter. The winding-off sheave has three grooves of different diameters, so that the pitch of the strands may be altered. A counter driven by the return sheave records the length of rope made.

1422. Wire rope machine. Contributed by W. Smith, Esq., 1872. M. 1266.

This machine is similar in its action to No. 1421, but strands together 36 wires round a central core which is led from a fixed external bobbin. The small diameter of the individual wires renders the rope very flexible, while their number gives the required strength.

1423. Cord-covering machine. Contributed by J. Lewis, Esq., 1860. M. 383.

This machine, patented by Mr. W. H. Zahn in 1855, is for wrapping the strands of a cotton cord with silk, and then laying the strands together into a finished ornamental cord of possibly four differently coloured strands.

The machine is arranged vertically, with four bobbin frames projecting from a face plate, beneath which is a lantern ring that gears with a spur-wheel attached to each of the frames. Each frame carries two bobbins, a large vertical one holding the core material, and a small horizontal one supplying the covering silk, which is in the form of sliver. Above the bobbin frames is a disc, that steadies them and also carries guide sheaves leading to the lay-top; above all is a return sheave, round which the finished cord passes down to the winding-off rollers, which deliver it to a large reeling bobbin.

If the cord is merely to be covered without stranding it together, the lantern ring is alone driven, so rotating the bobbin frames and winding the silk round the core, as delivered, the twisting so introduced not being objectionable. If the four cords so covered are required to be stranded together, the lantern ring is held stationary and the upper disc driven, so that in addition to the covering action the four cords are closed together into a rope.

1424. Plaiting machine. Presented by Messrs. Douglas Fraser & Sons, 1889. M. 2282.

This is a machine for plaiting wicks for candles. Before the introduction of plaited wicks, unconsumed carbon accumulated at the top of the wick, and greatly reduced the luminosity of the flame, which was only restored by the removal of the top of the wick by snuffers. By plaiting the wick, the free end, as the candle burns, has a tendency to curl over, thus bringing it into a portion of the flame where carbon is completely burnt, so preventing any accumulation.

In this machine the cops of cotton from which the wick is made are arranged on a stationary creel at the back. The 45 threads are made into three equal strands, which pass through the eyes of three equidistant tubular arms, oscillating round horizontal axes carried in stationary bearings. These arms are moved by a double cam, cut on a central vertical cylinder, and owing to their circular motion do not vary the tension in the strands. The three strands meet in the centre of the machine, where there is an eye attached to a revolving frame that carries the bobbin on to which the plaited yarn is wound. As the arms rock up and down, the frame carrying the bobbin acts as a shuttle in passing alternately above and below the respective strands from the three arms. The machine is driven by power from below, and is provided with an automatic motion that stops it should any thread break. From its cop each thread passes between tension pegs and then under a hook on a weighted lever. Should any thread break its lever drops, and so is struck by a revolving bar which then throws the driving belt on to the loose pulley.

Early plaiting machines had the bobbin moving in a figure-of-eight course, and could only be run at a low speed. This machine works at 600 revs. per min., turning out 90 in. of wick, with 10 folds to the inch each side.

1425. Lang's wire rope. Presented by Messrs. George Cradock & Co., 1894. M. 2723.

In round wire ropes of ordinary construction, the component wires of their strands are twisted in one direction, whilst the strands forming the rope are closed the opposite way about. With hemp ropes this arrangement is necessary to secure a firm result, and it also simplifies splicing. In 1879, however, Mr. John Lang introduced wire ropes in which the wires forming the strands, and the strands themselves were all laid in the same direction. The result is that such a rope, when passing over a drum, has a longer continuous bearing for each individual wire, as the crowns are less pronounced, and consequently the cutting tendency is reduced. In this way the life of a wire rope for running or winding is considerably increased owing to the more uniform wear experienced throughout the component wires.

Four specimens of rope are shown: No. 1 is a new rope of ordinary lay 2·5 in. circumference. No. 2 is a portion of similar rope much worn. No. 3 is a new rope closed in the manner introduced by Mr. Lang. No. 4 is the same rope worn down to less than 2 in. circumference.

PAPER-MAKING.

Before the invention of paper, use was made of many natural products that could be obtained in thin sheets, such as the inner and light-coloured bark of trees like the linden, parchment made from the skins of animals, and the papyrus of the Egyptians, which consisted of strips of the pith of a sedge-like plant pasted crosswise in layers. These were all expensive and unsatisfactory substitutes for paper, which is essentially a thin felted sheet of vegetable fibres consisting chiefly of cellulose.

Paper made from silk waste was used by the Chinese 300 B.C. They are believed also to have been the first to make paper from linen rags. The art was introduced into Europe about the middle of the 12th century, and subsequently a paper mill was erected in England by John Tate, at Stevenage, but nothing further is recorded till 1558, when mention is made of a mill at Dartford, established by a German named John Spielman.

The methods adopted by the earliest paper-makers are not known, but up to the end of the 18th century paper was entirely made by hand, the largest sheets being "antiquarian" (53 in. by 31 in.). In 1798 Louis Robert, a clerk employed by MM. Didot, the celebrated paper-makers of Essones, near Paris, made a model of a machine for making paper in continuous lengths. This was brought to England by Mr. Gamble, who introduced it to the notice of Messrs. H. & S. Fourdrinier and Mr. Bryan Donkin. In 1804 they erected a mill at Frogmoor, surmounted the mechanical difficulties, and obtained a patent in 1806, but the enterprise was not at the time financially successful. Machine-made paper has now superseded hand-made for all but a few special purposes.

As early as 1765 the desirability of obtaining additional sources for the supply of paper-making materials, besides rags, was discussed, and a large number of vegetable fibres were tried. The chief difficulty found, however, was to obtain suitable material in sufficient quantity and at a low price. The few that are now largely used are straw, which was first employed more than a century ago; esparto grass, which was commercially introduced by Mr. T. Routledge in 1857; and chemically prepared wood pulp, which, while now of the greatest importance, has only come slowly into use since 1865.

Paper from Rags.—The earliest recorded process was to sort and cut the linen rags, clean them from dust and dirt by beating, and then wash the material in puncheons. It was afterwards stacked in heaps for from six to twenty days, when fermentation softened the fibres so that the mass could be reduced to pulp by being pounded in oaken mortars by trip hammers driven by a water-wheel. The pulp so formed was taken to vats, where a workman with a shallow tray that had a bottom of wire gauze lifted a tray-full of the fluid mixture. The water running through the meshes left the solid matter in a sheet on the gauze, and this sheet was then turned out upon a cloth and pressed until it was sufficiently dry to be hung up. It was afterwards sized to prevent the ink running, the size closing the pores on the surface. The "watermark" in hand-made paper is a pattern formed by working the device in wire in the bottom of the tray. The elevation caused by this extra wire causes the pulp deposited upon it to be thinner there than elsewhere.

The process now adopted, after the rags are sorted and cut, is to knock out the dust in a "willow," then boil the rags by steam in an alkaline solution for 10 to 12 hours to get rid of grease and some of the dirt and colouring matter. The rags are next submitted for two or three hours to the action of the washing and breaking engine, an oblong box with semi-circular ends and a midfeather. In one compartment is a heavy iron roll provided with knives on its periphery, rotating against fixed knives. The rags are by this engine washed free from dirt and excess of alkali, and at the same time the fibres are torn apart. When nearly completed, a bleaching solution is introduced and thoroughly incorporated, after which the pulp is run into slate cisterns, where it remains for 24 hours to complete the bleaching. The material next passes to the "hollander," or beating engine, invented about the middle of the 18th century to replace the slower mortars, although the latter preserved the fibres better and made a paper of greater strength. The beater much resembles the breaking or rag engine, and in it the china clay or other loading material is introduced. This is not altogether an adulteration, as it enables the paper to take a better finish. For writing papers it is now usual to size the pulp, or it may be done on the finished paper

by a soap of resin dissolved in soda and treated with alum. Colouring, if required, is then added, and the pulp is finally run off into circular stuff-chests fitted with agitators, whence it is delivered by stuff pumps to the Fourdrinier paper-making machine (*see* No. 1430). This remarkable machine receives the material as a stream of pulp, and delivers it as a continuous roll of finished paper, or in cut and trimmed sheets.

Paper from other Materials than Rags.—The processes for the preparation of the pulp differ with the material. Wood pulp is prepared by mechanical and chemical means. By the first method, introduced by Völter in 1867, blocks of soft wood are digested by steaming and then pressed against revolving grindstones that tear off the fibres, which are washed away by a continuous stream of water. The fibres, being short, have but little felting power, and, owing to the lignin or non-cellulose constituent being left in this pulp, paper made from it in time turns yellow. In the chemical process the wood is first sawn into small logs, stripped of its bark and split into boards, from which the knots are cut out. The boards are then broken into small chips, which are bruised under heavy rollers, and screened to remove dirt. The chips are treated in a boiler with either caustic soda, sulphate of soda, or sulphurous acid. In the case of straw or esparto, it is freed from roots, weeds, &c., cut into lengths of about ·8 in., and boiled with caustic soda in stationary vomiters. A washing engine is then used, and after bleaching, colouring, &c. as before, the pulp is ready for the stuff-chest. Jute is treated more like rags, being boiled in rotaries with lime, but it requires powerful bleaching owing to its dark colour.

1426. Model of rag duster. (Scale 1 : 8.) Made by Messrs. Bryan Donkin & Co., 1892. M. 2438.

This is a model of a machine used in paper mills, for removing dust from rags. A long gauze cylinder, with its axis inclined and fitted inside with projecting beaters, is caused to rotate; at the same time a spindle running through the centre, and also fitted with beaters, rotates at a much higher speed in the same direction. The rags, which are fed into the upper end of the cylinder, either by hand or by an endless belt, are tossed about by the beaters while travelling down the revolving inclined surface. The dust and dirt, thus shaken out of the shredded rags, fall through the gauze cylinder into the chamber below. The machine is driven by steam power, the wire cylinder making 12 revs., and the central shaft 75 revs. per min. The amount of rags treated varies from 400 to 2,400 lbs. per hour.

1427. Model of rag boiler. (Scale 1 : 8.) Made by Messrs. Bryan Donkin & Co., 1892. M. 2437.

This is a model of a spherical rotary boiler, for boiling rags under steam pressure, preparatory to their being manufactured into paper.

The boiler is made of wrought iron, steel, or copper, the latter being used when chemical bleaching is combined with the boiling. The interior is fitted with projecting forks for stirring the rags as the boiler rotates.

Steam is admitted through the gudgeons, and the boiler is steadily revolved by worm gear driven from the factory shafting. The average time for treating a charge is from 10 to 20 hours, and the boiler makes from 1 to 3 revs. per min. The full-sized boiler is 8 ft. diam., and holds 1·25 tons of dry rags. A cock for blowing off the water is fixed opposite the charging door.

1428. Model of rag engine. (Scale 1 : 8.) Made by Messrs. Bryan Donkin & Co., 1892. M. 2440.

This is a model of a machine for reducing boiled rags, esparto grass, straw, or other material to the form of pulp, for paper-making.

A horizontal drum is fitted with a set of knives, by whose rotation, against blades fixed at the bottom of a trough, the rags are reduced. The trough is annular in plan, so that the contents by continuous circulation shall repeatedly pass under the drum, which rotates at about 200 revs. per min. for ordinary commercial papers. Both the stationary and revolving knives are made of steel, but for bank-note paper they are constructed of brass.

1429. Drawing of Sinclair's chemical wood pulp plant. (Scales 1 : 48, 1 : 24, and full size.) Lent by J. McNicol, Esq., 1874. M. 2916.

The method of preparing cellulose fibre from wood by means of caustic soda, in order to obtain pulp for paper-making, was patented by Watt and Burgess in 1853, and improved by Houghton in 1857 and Sinclair in 1869–72. The pulp produced is not suitable for paper of the best quality, owing to the action of the caustic soda, and although still largely employed abroad the process is being superseded by others involving the use of calcium or magnesium bisulphite, first patented by Tilghmann in 1866.

The Sinclair plant shown in the drawing is suitable for pulping wood, esparto, or straw. White stringy woods, such as pine or poplar, are preferred; the logs are sawn into short lengths, barked, split, and the knots cut out. The wood is then cut up by the chipping machine (Fig. 6) and the chips are charged into the top of a vertical digester of boiler plate, into which is run a hot lye, containing caustic soda to the extent of about 20 per cent. of the weight of the chips. The whole is then boiled by steam at a pressure of 10–14 atmospheres for 10 or 12 hours. Steam is supplied by a tubular boiler, of which Figs. 8 & 9 show details.

1430. Model of continuous paper-making machine. (Scale 1 : 8.) Made by Messrs. Bryan Donkin & Co., 1858 and 1889. Plate VIII., No. 1. M. 49 & 2264.

In this machine the material enters as pulp and is delivered as finished paper in a continuous roll of unlimited length. This method of manufacture was proposed by Mons. Louis Robert, at St. Étienne, near Paris, in 1798, but was brought into actual use by Messrs. H. & S. Fourdrinier and Mr. Bryan Donkin at St. Neots in 1808. An adjacent lithograph shows the arrangement of this original plant, which differed considerably from that now adopted.

The model represents a complete Fourdrinier machine with its accessories. The prepared pulp is run into two stuff-chests lined with enamel and provided with agitators to keep it of uniform consistency. A pipe from each chest leads the pulp into a mixer, into which flows water that is being drained from a wire apron used later in the process, and a force pump delivers the mixture into a supply box provided with slides to regulate the outflow. The delivery is upon a slightly inclined tray formed of wooden slats sloping in the opposite direction to the flow and acting as a sand trap. The mixture then passes over either of two alternative strainers, invented in 1830 by Mr. Richard Ibotson, which keep back knots and other large

particles. The strainer in position is formed of a series of grooves cut in a metal plate, through slits at the bottom of which the pulp passes, while the other consists of a series of bars placed side by side and very close together. Both are hinged on the side next the machine and on the other side are provided with projections which are acted on by tappets on a revolving shaft, thereby receiving a jogging motion which assists the passage of the pulp into the trough below, whence it flows over a moleskin or india-rubber apron, resting on the breast roll. This delivers it on to an endless travelling wire cloth, of 60 to 70 wires per lineal inch, stretched between rollers and kept level by numerous supporting rollers. The width of the paper to be made is determined by thick belts, or deckle straps, of india-rubber, usually square in section, resting on the wire cloth and travelling with it. The whole frame of this apparatus is given a side "shoggling" or vibratory movement from one end by a crank motion; the number of vibrations may be adjusted from 100 to 200 per min. and the amplitude from ·25 to 1 in. The object of this motion is partly to shake the pulp free from water, but principally to make the fibres interlace with one another. The water is further removed from the paper by passing the apron over a vacuum box with a perforated top, through which the water is exhausted by three-throw vacuum pumps, that deliver it into a cistern from which a force pump discharges it upon the sand traps. If a watermark is desired, it is impressed by a dandy roll, 7 or 8 in. diam., covered with wire-wove cloth having the watermark in relief.

The tender sheet of paper is now able to bear the pressure of the coucher rolls, placed at an angle, which press out most of the remaining water and deliver the paper upon an endless felt or blanket; this leads it between two sets of felt-press rolls which take out the marks of the wire cloth. The water which drains away from the wire cloth, &c., contains a large amount of valuable fibre which flows back into the mixing vat. The wet paper is now taken, on an endless felt, round drying cylinders supplied with live steam through their trunnions (in the model one small and five large cylinders are employed). The paper then passes between smoothing rolls, then round a further set of drying cylinders and finally through two stands of three-roll smoothing calenders, to give a final gloss to the surface. The finished paper is then wound in a continuous web upon rollers contained in a reversible frame, or an arrangement may be fitted which cuts the web into widths and thence into sheets of any required size.

The whole plant is driven by shafting, usually placed below the floor level.

1431. Envelope-making machine. Lent by Messrs. Thomas de la Rue & Co., 1888. M. 1925.

Envelopes were little used before the introduction, in 1839, of a uniform rate of postage by weight; under the earlier system of charging by the sheet, the envelope might double the postage so that the usual practice was to fold the letter itself.

At first envelopes were all made by hand; the blanks were cut out of a pile of several sheets of paper by sharp cutters worked round the edge of a template placed on the top; they were then folded with a bone knife or folding stick, gummed, and embossed if necessary. In this way a good workman could turn out 3,000 per day.

The first application of machinery was the employment of a fly-press to cut out the blanks, which now are cut 250 at a time from piles of diamond-shaped sheets by a treadle or power press; punches with knife edges shaped to the outline of the blanks are used for usual sizes, while for exceptional ones the sheets are cut rectangular and the entering angles afterwards trimmed. The next machine employed was for creasing the paper, which it did by placing it over a rectangular box into which a plunger entered.

In 1845 Messrs. Edwin Hill and Warren de la Rue patented a machine which creased and folded the envelope blank, and in 1849 the latter improved it into the machine shown, which also embosses, gums, and finally presses the finished envelope. The operator sits in front of the table, having before him a pile of cut blanks, each with the seal flap gummed and dried. Those he places one at a time on a frame, where they may be embossed with the maker's name, &c. The frame is then moved by a rack and pinion into the centre of the table, and there deposits the blank over a rectangular hole, of the size of the finished envelope. Into this hole a built-up plunger descends and so creases the four sides of the blank. The opposite sides of this plunger now rise, and two angular folding flaps, one working slightly in advance of the other, completely fold over the side flaps of the envelope and hold it while the other two sides of the plunger rise. A V-shaped gummer, that has been in contact with a felt band revolving slowly in the gum trough, then descends upon the envelope, gums the side flaps and returns to the band; the bottom flap is now folded over in a similar way to the sides, and then the seal flap. Finally, two spring fingers, faced with india-rubber, carry the envelope on to an endless felt band, by which it is passed between pressing rollers and stacked in a receiving box. A counter is attached to register the number of envelopes made, which was about 3,000 per hour.

Nearly every motion in the machine is derived from cams on the main driving shaft.

WRITING AND COPYING.

Writing.—The earliest records are in the form of characters or hieroglyphics cut into stone or moulded in clay by a metal tool or graver; the next step was probably the use of a wood tablet covered with wax, upon which the symbols were scratched with the stylus, a metal bodkin pointed at one end for writing, and flattened at the other for erasing. The use of parchment and a fluid ink necessitated the employment of a pen, the earliest recorded form of which was a hollow reed pointed and slit like our quill pens; such reed pens are still used by the Arabs. Quill pens are alluded to as early as the 7th century A.D. The Chinese and Japanese write with a brush or hair pencil.

Metallic pens are not altogether a modern invention, as bronze pens have been found at Pompeii, and they appear to have been made occasionally during the Middle Ages, but more as curiosities than as articles of general use. In 1780 Harrison, of Birmingham, made a pen for Dr. Priestley in which a thin sheet of metal was bent to form a tube, and the end finished off like a quill, while the joint in the tube gave the split nib. In 1803 such pens were sold in London at 5*s*. each, afterwards reduced to 6*d*. In 1808 Bryan Donkin patented a metallic nib, Λ-shaped in section, which with its slit ridge was more flexible than the cylindrical form, and these pens were commercially manufactured. Joseph Bramah in 1809 patented a machine for cutting up a quill into a number of nibs, and these two inventions mark the introduction of a pen detachable from its holder. James Perry in 1830 patented a method of giving elasticity to the

cylindrical nibs by means of side slits, and to him belongs the credit of bringing steel pens into general use. With the assistance of Sir J. Mason & John Gillott, of Birmingham, the trade was revolutionised by the introduction of machinery, and soon became a flourishing and important industry.

A fountain pen, in which a considerable reservoir of ink could be carried, was invented by J. Bramah, but the first successful one was not brought out till 1848. The stylograph, patented in 1879, has a point like a stylus tipped with iridium, and pierced with a fine aperture, through which projects slightly a fine wire that assists and regulates the flow of the ink. Several improvements have recently been effected in fountain pens, the latest type of which is self-filling.

Copying.—The drudgery and expense of copying manuscript by hand has led to the invention of many processes for obtaining a limited number of copies with less labour. Brunel's multiple writing machine is a device by which the writer operated several pens that were connected together by linkwork (*see* No. 1436). Manifolding, invented by Ralph Wedgwood in 1806, and now largely used in telegraphic work and for trade purposes, is a more convenient device. He used paper that had been covered with printing ink and dried for about six weeks. This, when interposed between sheets of white paper gave, throughout the pile, copies of the writing done on the upper sheet with a pencil or stylus.

Press copying, introduced by James Watt in 1780, still remains the most convenient method of obtaining one or two copies of correspondence for business purposes. A special ink containing sugar or gum is used to write the original and, when dry, a sheet of damp paper pressed against it removes sufficient of the ink to give a copy that can be read through the thin copying paper. Watt proposed both the screw press and the roller copying press, but preferred the latter (*see* No. 1437), as copying in books was not then practised. For copying on to thicker paper, and for giving numerous copies, a process somewhat resembling lithography, but requiring no ink rollers or press, is well known. The original is written with an aniline ink, and then placed on a soft gelatinous surface, when by rubbing the back of the paper much of the ink is absorbed into the gelatine; then by placing white sheets on the surface and using gentle pressure, 50 or 60 copies may be obtained from the ink transferred.

Stencils prepared by various methods, and used by passing an inked roller over the back, are now largely employed. In the trypograph introduced by Zuccato (*see* No. 1443), the stencil is prepared by placing a sheet of impermeable paper on a hardened steel plate with its surface cut like a fine file, and writing on it with a hard point which, by the concentrated pressure, renders the paper permeable. In the cyclostyle, the instrument used for writing has on its extremity a minute

wheel with very fine spikes which puncture the paper. The stencil may also be prepared by the use of an electric pen or similar mechanical perforator, and it is found that a waxed sheet can be rendered sufficiently porous locally for use as a stencil, as in Edison's mimeograph, if passed through a typewriting machine using caustic soda instead of ink.

1432. Quill pen cutter. Presented by Messrs. William Mitchell (Pens), Ltd., 1907. M. 3482.

Quill pens are still, as formerly, cut with a knife: the skill necessary for cracking the slit and forming the nib are only attainable by long practice. To obviate this, more particularly in mending an old pen, the tool shown was brought out in this country, it is believed, in the middle of the 18th century. Its product is not, however, equal to hand work.

It has a pair of shear blades hinged together, between which is inserted the quill roughly cut to shape by the knife blade that slides into the handle. The upper shear blade is forced down by the thumb and a fixed knife below cracks the slit. The point can be cut to the required width by the spring snips.

1433. Early steel pens. Lent by Bryan Donkin, Esq., 1876 and 1888. M. 1948.

In 1808 Mr. Donkin patented the form of pen shown, in which he avoided the extreme hardness of the steel cylindrical barrel by forming the nibs of two flat pieces meeting at a ridge, where their junction forms the slit. Several specimens of this pen are shown, some constructed of two separate pieces brazed together at the back end, and some by bending a sheet and cutting the slit. The pierced hole between the nibs is seen in some of these. The sheet steel used appears to have been 23 I.W.G.; to increase the flexibility, the edge of the nibs have been greatly reduced in thickness. An original advertisement of these pens is also shown.

1434. Embossing frame for the blind. Presented by the London Society for Teaching the Blind, 1852. M. 2932.

This apparatus was the invention of Mr. Wood, formerly master of the Society's schools. It is intended for use with the stenographic characters invented by Mr. T. M. Lucas, of Bristol, about 1835, a series of arbitrary signs said to be founded on Byron's system of shorthand.

The paper is fixed on a baize-covered board, across which extends a bar guided by a series of holes along the two edges of the board, that give line spacing. On the cross-bar is a rack, which spaces the successive movements from left to right of a sliding eight-pointed socket. The characters are in relief on a stamp having 10 arms, each of which can be passed into the socket in eight different positions.

1435. Writing tablet for the blind. Contributed by the Rev. Gilbert Wardlaw, M.A., 1862. M. 794.

Writing frames for the blind. Received 1862 and 1871. M. 2934–5.

The first is a device to assist the blind when writing, by securing uniform margins and equal spacing between the lines. It consists of a board upon which the sheet of paper is placed; above it is a metal plate having a slot across it, wide enough for one line of writing. Wires at each side of the board indicate the margins. The paper is held by a clip, which has on its

underside a tooth that fits into a rack secured to the board and parallel with the sides; the paper can by this means be drawn up the same amount every time a line is completed.

A Swedish and a Belgian modification of this frame are also shown.

1436. Multiple writing machine. Presented by R. B. Prosser, Esq., 1891. M. 2408.

This machine was patented in 1799 by Sir M. I. Brunel as a means by which "two or more writings or drawings resembling each other may be "made by the same person at the same time." The desk portion shown is, however, not original, but has been made to the patent drawing, except that it is not constructed to fold up.

Two quill pens are carried by vertical swinging V-shaped arms connected by a light rod below, and supported above by two scale-beam levers, so coupled that when one pen is lifted the other is raised to the same amount, while the swings permit of the to-and-fro motion. The two scale levers are carried in a long wooden frame swinging on trunnions at the centre of its ends, thus providing for the sideway movement of the pens. To permit of the larger movements requisite to command the whole of the paper, the latter is placed on a sliding leaf on the desk, and the swing frame is mounted in another frame carried on wheels running on rails. The operator guides the lower pen by means of a handle held like an ordinary penholder, and connected to the lower pen by a universal joint. Each pen is provided with a separate ink well, so that the pens are refilled at the same time from their respective wells.

1437. Roller copying presses. Woodcroft Bequest, 1903. M. 1837.

These two roller presses were constructed and patented in 1780 by James Watt, in connection with his invention for copying letters. The process is essentially the same as that now generally adopted, but at first the copying paper was kept damp in a damping box, instead of being wetted with a brush as required. The necessity for using a special ink was recognised, and suitable powders were provided for its preparation. The loose tissue copies were kept in a book or portfolio, the present copying book being a later introduction. The presses shown have each two metal rollers, the upper of which can be turned by a hand lever fitting on the axis, and two pasteboards covered with cloth are provided to hold the papers while being passed between the rollers. Watt also tried the screw press, but, until the copying book came into use, rolls were apparently preferred, as his own writing-desk is fitted with a roller press. An early copy made by this process is shown, and also some original pamphlets describing the invention.

1438. Hydraulic copying press. Presented by A. W. Tuer, Esq., 1879. M. 1469.

This letter-copying press was patented by Joseph Bramah in 1795. The example shown was made by Messrs. J. Bramah & Sons about 1801, and differs from the ordinary screw press in that the pressure is applied by a ram 1·25 in. diam., which is driven upwards by water forced by a pump ·5 in. diam., which is fixed on a small tank at the side of the bed, and worked by a hand lever. The total mechanical advantage from handle to ram is 1 : 37. A return valve lets the water pass from the cylinder to the tank when the pressing is finished.

The ram has such a short travel that the press was evidently not intended for use on a copying book, but merely for single sheets of large post folio size (16·75 in. by 10·37 in.). A tinfoil-lined mahogany box was fixed on the top of the press, probably for holding the damping sheets.

1439. Letter-copying press. Presented by Messrs. John Poole & Sons, 1907. M. 3497.

The distinguishing feature of this press, which dates from the early part of the 19th century, is the use of a toggle-joint for obtaining very great closing pressure.

The bed of the press is trough-shaped and is supported on four turned legs. The platen is adjusted to suit the thickness of the copying book, &c., by nuts on two screwed rods pinned to two levers close to where they are centred on the bed-casting, The levers are linked to a block also centred in the bed near its middle. This block is oscillated by a rod from a bell-crank handle, the crank and the rod constituting the toggle; considerable mechanical advantage is also obtained from the levers. The press is of post folio size (15·5 in. by 9·5 in.).

1440. Lever copying press. Presented by Evan Hare, Esq. 1902. M. 3226.

James Watt, when he introduced the system of press-copying letters, usually obtained the requisite pressure by the use of rollers and these were very convenient so long as the work was confined to single sheets. When, however, the practice of copying into books became common, the screw press, which Watt had also tried, was generally preferred owing to the readiness with which it adapted itself to books of varying thickness.

In the press shown, which was introduced by Patrick Ritchie, of Edinburgh, early in the 19th century, the pressure is obtained by the use of a cam moved by a hand lever, while the upward or return motion of the platen is given by a plate spring. The necessarily short throw of the cam would have prevented copying books of varying thicknesses being used but for the introduction of a screw between the cam and the platen, by which the machine is adjusted before the copying pressure is applied to suit the thickness of the book in use.

1441. Original electric pen. Presented by T. A. Edison, Esq., 1880. M. 1483.

This instrument was patented by Mr. Edison in 1875. By its means a paper stencil plate is rapidly prepared which can be used for producing a large number of copies or prints of the original writing, simply by running an inked roller over the back of the stencil.

The instrument consists of a stylus from the end of which projects a needle point; the needle is connected to a small flywheel and electric motor, at the end of the instrument, and by the rotation of the motor the point is very rapidly protruded and drawn back again, so that in passing over a sheet of paper the track of the stylus is left finely perforated. The current is supplied by flexible conductors.

1442. Perforating pen. Contributed by Messrs. Newton Wilson & Co., 1880. M. 1494.

This instrument is used somewhat like an ordinary pen, but held in a vertical position, and is for preparing stencil plates similar to those produced by the Edison pen (No. 1441).

The needle point has a stroke of ·01 in., and is driven by a wound spiral spring and gearing, contained in a metal case at the upper end of the instrument.

1443. Trypograph. Received 1908. M. 3535.

This stencil copying apparatus (*lit.* "hole writer") was patented in 1877 and 1887 by Mr. E. de Zuccato.

The stencil is made from thin paper waterproofed with wax, &c.; the paper is supported upon a hardened steel plate whose surface is cut like

a smooth file, the minute points of which perforate the paper when written upon firmly with a hardened steel stylus.

The stencil is clamped face upward by the two brass bars on the sides of the box. The lid between them is hinged so that it can drop for the purpose of inserting the paper to be printed on. Thin printing ink is brushed evenly on the stencil at one side; it is pushed by the squeegee slowly over the stencil and passes through the minute holes on to the paper beneath. It is stated that a maximum of 5,000 copies can be obtained. The apparatus shown is for foolscap size.

PRINTING MACHINERY.

Block printing, in which an inked impression is taken from a wooden block on which the design or letterpress has been left in relief by cutting away the surrounding wood at the surface, is the earliest method of printing and was in use in Germany in 1423. The value of a screw press, for giving while printing a greater pressure than could be obtained by simple hand pressure, was discovered soon afterwards.

Copper-plate printing, which was invented about 1446, requires that the design shall be engraved in a polished sheet of copper. This is then inked over and the surface wiped clean so that ink only remains in the engraved lines; a damped sheet of paper powerfully pressed upon the plate receives an impression by taking up the ink left in the lines. The presses first used were probably the same as for letterpress, but the roller press for copper-plate work was employed as early as 1545. Such presses were worked by manual power but quite recently steam-driven presses of great strength have been used for map-printing from copper plates upon dry paper, so avoiding the contraction error.

Copper plates are usually prepared by engraving or else by etching, but for certain subjects the plates have been prepared directly without the assistance of an artist. The object makes its own impression upon a sheet of gutta percha or lead and from this by electrotypy a working plate is obtained (*see* No. 1464). By this " nature printing " process, the illustrations in Moore's " Ferns of Great Britain and Ireland " were prepared in 1855.

Lithography was invented in 1796 by Alois Senefelder, of Munich, who printed a piece of music by this means. The process turns upon the readiness with which polished limestone will absorb grease or water, and the way in which the presence of either of these fluids will afterwards prevent the absorption of the other. The drawing or writing is made on paper with a greasy ink, and then placed face downwards upon the stone and pressed so that the ink enters the stone. The paper is removed and the face of the stone moistened with water and a

roller charged with fatty ink passed over the surface, when the ink only adheres to the greasy portions so that a sheet of paper afterwards pressed on the stone will only be printed from these portions. The great advantages of lithography are its economy, expedition, and the very large number of copies which can be obtained from one stone, as many as 70,000 having been taken. Chromo-lithography is simply the successive printing on the same sheet of the various colours in a picture by this process. Zincography, the invention of Eberhard, consists chiefly in the substitution of a prepared zinc surface for the stone of the lithographer.

The first lithographic presses used were simply the early screw printing presses; the stone was placed on a carriage over which the tympan holding the sheet of paper was folded down, and the pressure applied by a platen forced downwards by a screw. The stone was inked and damped by hand after each impression, the inking roller being made of wood covered with flannel and calfskin. In 1860 the single-cylinder printing machine was applied to lithographic work. The stone was secured on the reciprocating table, which had a vertical adjustment to suit the varying thickness of the stones. The sheet was fed in on the top of the platen cylinders by grippers, while at one end of the machine were placed damping rollers and at the other leather-covered inking rollers, and an ink trough, ductor roller, and ink-distributing table. This is the style of machine now generally employed in this work.

Typography, or the art of printing from movable type, was invented in Europe about the middle of the 15th century; beyond this fact the history of this far-reaching invention is very uncertain. It is generally considered that cut wooden type were first used, then cut leaden type, and that afterwards cast type were employed. William Caxton in 1476 was the first to practise printing from movable type in England.

For bookwork, pages of proper width and length are set up with the aid of a composing stick, and an even number of them, varying with the size of sheet to be printed on, are cramped in a wrought-iron rectangular frame, or chase, by means of wood packing, so forming a rigid mass, or forme, which may be moved about. For modern newspaper work, the composing is usually done by machinery. The linotype, first made in 1884, and introduced into England in 1891, is the earliest of such machines. In its perfected form, the operator controls a keyboard, similar to that of a typewriter, the instrument comprising mechanism for composing and justifying the matrices, casting from them when they complete a line, and redistributing them back to their places, the whole series of operations being continuous and automatic. With this machine a single operator can compose at about four times the rate of hand work.

Stereotypy for bookwork is only resorted to when a very large edition is to be printed. Stereotypy and electrotypy are branches of typography. Stereotypy was invented about 1725 by William Ged, a goldsmith of Edinburgh, who employed plaster of Paris to make the mould, but in 1839 these moulds were superseded by the present papier-mâché ones, introduced by Genoux. To prepare a stereotype plate the forme of type is first oiled and then the "flong," made of several plies of paste and paper, is beaten into it with a stiff brush; when thoroughly embedded it is stripped off, dried quickly, and placed on the bed of a casting box with gauges to determine the thickness of the stereotype, usually .16 in. (*see* No. 1463). For cylinder printing, the papier-mâché mould is bent to fit the cylinder, and the inside core of the mould is of the same diameter as the printing cylinder, but in some works the plates are cast flat and afterwards bent to the required curvature. The great advantages of the papier-mâché moulds are that they can be bent and also be repeatedly used, which was not the case with those of plaster.

Electrotypy is one of the many useful applications of Wollaston's discovery in 1804 that a metal can be deposited from a solution of its salt by the action of an electric current. The method now adopted is to brush the forme with finely powdered plumbago and squeeze down upon it wax in a plastic state mixed with a little plumbago. Upon this impression copper is electrically deposited until a thickness of .031 in. is attained, when the copper is removed and strengthened by a backing of typemetal which brings it up to the standard thickness (*see* No. 1463). Electrotypes, being harder, last longer and give finer impressions than stereotypes.

Typographic printing machinery may be broadly classified into: platen presses, in which a flat plate presses the paper on to a flat forme; cylinder machines, in which the forme is flat and the sheet is pressed upon it by a cylindrical platen or roller; rotary machines, in which both the forme and the platen are cylindrical.

Platen presses were used by the early printers indifferently for block, copper-plate, letterpress, and lithographic printing. The earliest representation of a press is dated 1507; it shows a quick-threaded screw worked by a hand lever, and a movable carriage with the tympan hinged to it. The platen press was improved in detail between 1601 and 1620 by William Blaew, of Amsterdam, who left it in a state in which it remained for nearly 200 years (*see* Nos. 1444–5), until Charles Mahon, third Earl Stanhope, at the close of the 18th century, invented the press which bears his name. By reason of the increased rigidity of the machine, owing to the exclusive use of iron in its construction, and by the employment of the mechanism known as the Stanhope levers, whereby a higher pressure and a

limiting stroke were obtained, he was able to print a sheet of double the size formerly possible (*see* No. 1447). In 1817 George Clymer, an American, patented the Columbian press, in which the screw and Stanhope levers are replaced by a toggle-joint. Many other hand presses appeared about this time, but none materially increased the speed of printing, which remained at a maximum of about 125 "perfect" sheets per hour.

Inking the type is an operation upon which the quality of the printing very greatly depends; if irregularly done, by an excess at places, the spoilt black-looking sheet was known as a monk, while if the inking was deficient, the lighter sheet was a friar. For about three centuries, the inking was done by hand, the printer using two balls made of skins or pelts, stuffed with horsehair, and provided with a wooden cap or handle. A little ink, previously worked up on a smooth stone, was placed on one ball, and worked between the two till evenly distributed, when the balls were applied to the type. In Koenig's first machines of about 1810, the inking was done by leather-covered rollers, and in 1813 Messrs. Bacon & Donkin introduced inking rollers made of a mixture of glue and treacle, similar to those now used, of which, however, the composition is usually glue and glycerine.

Cylinder Machines (*single and perfecting*).—In a remarkable patent taken out in 1790 by William Nicholson, editor of *The Philosophical Magazine*, are anticipated many of the subsequent improvements that have led to rapid printing, such as the use of inking and distributing rollers, the ink trough, and the plan of fixing type or plates on the surface of a cylinder. Nicholson, however, never carried his proposals into practice. Frederick Koenig, a German who settled in England in 1806, after having spent four years in trying to increase the speed of the platen press, abandoned it, and in 1811 patented a machine with a platen cylinder, tapes, and inking rollers. In 1814, the Times was printed by such a machine at the rate of 1,100 sheets per hour, increased later to 1,800. Koenig subsequently constructed another machine in which the path followed by the paper was like the letter ∾, the sheet being delivered printed on both sides or "perfected." In 1818, Edward Cowper introduced the flat distributing table and generally improved the inking arrangements. In 1827, Cowper and Applegath, having already simplified and improved Koenig's machine, constructed a single machine for *The Times* office, in which were four cylinders, printing alternately in pairs; it produced 5,000 single sheets per hour. They also introduced a perfecting machine embodying their combined improvements (*see* No. 1449). In 1824, David Napier introduced a perfecting machine with rising and falling cylinders actuated by a toggle-joint, and also provided with his double gripper feed motion. Thomas Main in 1850 brought out a machine in which the cylinder had its motion reversed and was therefore called a rocking cylinder; it was

either a single or double feeder. The Wharfedale (1858) is a similar machine to this, while others, such as the Bremner (1859) and the Graphic (1874) (*see* No. 1457), were designed for special purposes. These cylinder machines, printing from a flat forme yet with considerable speed, are preferred for the highest class of bookwork and illustrations.

Rotary Machines.—In 1813, Messrs. Bacon & Donkin constructed a machine in which the type were fixed on a four-sided prism, the platen-drum being another prism so shaped as to revolve with it, but the inking apparatus of this machine was defective. In a machine for printing wall-paper, patented by Cowper in 1816, he proposed to bend the flat stereotypes to the curve of a cylinder. In 1835, Rowland Hill patented a machine in which he employed type tapered on their sides, to form a true cylindrical surface; portions of the machine are preserved (*see* No. 1456). In 1848, Applegath brought out a machine with a central vertical cylinder 5 ft. 6 in. diam., round which were arranged eight platen cylinders 12 in. diam., each supplied with a feeding apparatus. The type were in flat galleys on the surface of the central cylinder, which was really polygonal, but departed from the circle to such a slight extent that it was no inconvenience; a similar nine-cylinder machine threw off 16,000 impressions per hour. In 1849, Mr. F. W. Bodmer discovered a means whereby the roll or web of paper could be damped as it was reeled off. In 1857, *The Times* adopted a machine, the invention of Col. R. M. Hoe, of New York, greatly resembling Applegath's but having its type cylinder horizontal, with six platen cylinders round it (*see* No. 1457); a similar machine with ten cylinders threw off 20,000 impressions per hour, and in the modern Hoe machine with eight cylinders as used in newspaper work, 100,000 eight-page copies can be produced per hour. In 1862, the proprietors of the paper began the construction of their Walter press, which was finished in 1866 (*see* No. 1457). Since then there have been numerous machines introduced for special work, several of which are described in connection with the wall diagrams (*see* No. 1457).

Recent improvements which have taken place are principally in the greater strength and rigidity given to the machines, the omission of any pad or blanket between forme and platen, the greater hardness given to the latter, and the use of dry highly calendered paper for the finest bookwork and illustration, instead of using it damped as heretofore. Tapes have almost disappeared, and rotary machines are now used for printing work of a class that until quite recently was confined to the slower cylinder machines.

1444. Caxton printing press. Presented by Charles Wyman, Esq., 1863. Plate VIII., No. 2. M. 935.

This is a very old hand press, at which it is said that Benjamin Franklin worked; it resembles the earliest known form of printing press.

The framing is of hard wood, mortised together; it carries two horizontal rails upon which slides a carriage supporting the frame of composed type, called the forme. The type was inked by two large pads, or balls, with ink on their surfaces, the distribution of the ink being performed by working the pads together and then applying them to the forme. Hinged to the carriage for holding the sheet of paper to be printed is the tympan, a double wooden frame (part missing), over which parchment is stretched with a pad of blanket between; hinged to the tympan is the frisket, a light iron frame covered with paper with a hole cut out of it as large as the forme, to keep the edges of the printed sheet clean; the latter is placed on the tympan, the frisket folded down on it and then all swung together over the forme. By two straps below, the carriage is connected to a winding drum, by which means it is moved along the rails to the other end of its travel; it is then immediately under a screw press by which the paper can be forced down upon the type with sufficient intensity. The screw is treble-threaded, 2·5 in. diam., 2·4 in. pitch, and is rotated through about 90 deg. by a hand lever 30 in. long. The upper end of the screw turns in a brass nut bedded into the framing, and the lower end is connected with a stout board, called the platen, by which the pressure of the screw is distributed over the tympan, which acts as a pad while pressing the paper on the type. When the screw is released the platen follows it up, owing to the upward pull of four thongs connecting the frame and the platen.

1445. Model of printing press. (Scale 1 : 6.) Bequeathed by the Rev. H. T. Ellacombe, M.A., 1885. M. 1632.

This complete working model of a hand press was made by the donor in 1812, and shows some of the details now missing from the early press, No. 1444, which it greatly resembles.

The tympan is shown turned back, so as to expose the forme of type and also the frisket holding a sheet that has been printed. The tympan is resting against a stop, which is missing from the Caxton press; the model also shows the balls for inking the forme, and the way in which they were supported when not in the printer's hands.

1446. Typefounding appliances. Presented by Thomas Bolas, Esq., 1900. M. 3127.

This is a collection of punches, matrices, and a mould as used from the introduction of cast type till the general adoption of that made by machine.

For each character a separate punch is prepared in tool steel and, when thoroughly finished, is hardened. Complete sets of these punches for different sizes of black letter, roman, and italic type, together with the headers, tail pieces, &c., are shown. The punch is used by hammering it into a piece of polished copper until a deep and clear impression, or matrix, is obtained for use in forming the end of the mould, in which the type will be cast; electrotypy has also been employed as a means of preparing a matrix from a punch; by either method a matrix can be speedily replaced when injured or worn, provided the punch is preserved.

The mould in which the type is cast is made in halves which are capable of sliding together sideways, so that it can be used for type of different widths, as determined by the matrix, which forms the bottom of the mould and is held in place by a spring. The mould has a bell-mouthed gate into which the typemetal is poured by means of a ladle holding exactly the right quantity; the workman when pouring gives the mould an upward jerk

which increases the sharpness of the casting. The sides of the mould are provided with non-conducting pads of wood to facilitate handling while hot.

1447. Stanhope printing press. Presented by Messrs. Adlard & Son, 1892. M. 2442.

The press shown is an improved form of the Stanhope made by T. Cogger, of Doctors' Commons about 1820, and embodies a modification patented in 1810 by Mr. A. F. de Heine, consisting in the use of inclined sectors on the top of the platen instead of a screw; the press was in constant use till presented to the Museum.

The machine has a heavy cast-iron frame and base, with rails upon which the type carriage is run under the platen by the usual drum and bands. The platen is depressed by the rotation of a short vertical shaft, which acts upon two circular inclines that virtually form a double-threaded screw. This shaft is rotated through 60 deg. by the pull of a connecting rod attached to a hand lever. These parts, which form the "Stanhope levers," are so arranged that at the time the connecting rod is passing its dead centre with regard to the hand lever, it is acting at its greatest leverage upon the vertical shaft. In this way a rapidly increasing mechanical advantage is obtained as the platen reaches the type, while only a constant amount of depression of the platen, adjustable at starting by a central screw, will be obtained whatever the pull exerted on the hand lever. All modern hand-presses act by such increasing leverage, now usually obtained, however, by a toggle-joint.

1448. Platen printing press. Received 1906. M. 3460.

This form of hand press, known as the Albion, was brought out about 1823 by Mr. R. W. Cope, although the principle adopted in its construction was made use of earlier. It is almost the only hand press now used, and then only where a limited number of impressions are required, such as proof-sheets.

The general construction. except that iron is used instead of wood, is similar to that of the earliest types (*see* No. 1444), the chief point of difference being that, in common with the Stanhope (No. 1447), the screw is discarded, the stroke of the platen is constant and its closing pressure on the type greatly increased.

In the Albion press this is accomplished by a toggle-joint, composed of a piece of steel with rounded ends and of a lever, at a slight inclination to one another. The steel bears in a cup in a casting to which the platen is bolted and the lever bears against the underside of the head of the press. This lever is connected by a link with the handle which, when pulled, brings the toggle into the vertical position and depresses the platen with rapidly increasing mechanical advantage as the type is reached. The stroke of the platen can be adjusted by a wedge underneath the cup on which the toggle bears. The platen is guided vertically by V-s and returned by a helical spring in a box placed on the head of the press and fixed to the casting above the platen by a bolt.

The capacity of the press is 250 post folio sheets printed on one side per hour.

1449. Model of perfecting cylinder printing machine. (Scale 1 : 8.) Received 1897. Plate VIII., No. 5. M. 2977.

This is a complete working model of a cylinder printing machine, containing the combined improvements of Edward Cowper and Augustus Applegath, patented in 1818 and 1823 respectively.

It is a "perfecting" machine, and consists essentially of two platen cylinders, carried in bearings by the framing and pressing upon two formes secured to a horizontal table which reciprocates below them. The sheet of paper to be printed is laid by the attendant on webs, or wide tapes,

stretched between rollers high up at one end of the machine. At the right instant the webs carry the sheet towards the adjacent platen cylinder, owing to a toothed segment on the cylinder engaging with teeth on the web roller. The sheet then enters between two sets of endless bands of tape, which lead it under the first cylinder, up between the cylinders, over and round, to below the second cylinder, the sheet being finally delivered in a horizontal position between the two cylinders. While passing under the first cylinder the underside of the sheet is printed by one of the formes on the table, and the course followed by the sheet is such that the other side is printed by the other forme while passing under the second cylinder, so "perfecting" the sheet.

To make this clearer in the model, one side of the sheet is being printed in black ink and the other in red.

The inking is performed by rollers, carried by the framing so that they rest on the type as the formes pass below. Between the two formes and moving with them is a flat metal plate called the distributing table, and at each end of the machine is an ink trough and ductor roller from which a vibrating roller takes a streak of ink and deposits it on the distributing table. On this table the ink is evenly distributed by small rollers, which, owing to the inclination of their axes, have a sliding as well as a revolving motion, as the table passes below them. The larger rollers that actually ink the formes gather their ink from the distributing table as it passes below them, and then roll it on to the forme as the motion continues. The whole table slides in guides formed on the side standards, and the reciprocating motion is given by a double rack driven by a vertical pinion, the arrangement somewhat resembling a mangle gear placed horizontally, but with the rack frame sliding instead of the pinion axis.

The machine represented would probably print about 5,000 "perfect" sheets per hour.

1450. Model of perfecting cylinder printing machine. (Scale 1 : 4.) Lent by T. B. Winter, Esq., 1889. M. 2267.

This is a larger model in wood of the Cowper and Applegath machine described in No. 1449. It shows, however, some improvements in detail, particularly in having the central drums placed higher so as to give more room over the receiving table.

1451. Model of printing press (working). (Scale 1 : 6.) Made by Messrs. Koenig & Bauer, 1905. Plate VIII., No. 4. M. 3429.

Friedrich Koenig in 1810 patented a form of printing machine wherein the platen of the hand press was replaced by a cylinder on which the sheet to be printed was held, all the movements for inking, &c., being at the same time rendered automatic. In 1811 at the "Times" office he erected a machine whence the development of the double cylinder, the perfecting (*see* No. 1449), and the rotary machine (*see* No. 1457) can continuously be traced.

The model shows the present form of the single-cylinder type, now used for all ordinary purposes. A belt-driven shaft, on which is a flywheel, by spur and bevel gearing drives a vertical shaft between the frames. On the rim of the bevel wheel is centred a spur wheel revolving inside a spur ring of twice its diameter; any point on the pitch circle of the wheel therefore describes a straight line. One such point is used as the attachment for the connecting rod to the carriage; the smooth running thus obtained is most marked in the large sizes. The carriage, on which is wedged the forme of type locked up as a chase, is guided by two V-shaped tracks, and the pressure at the printing point is taken by two rollers under the bed. The cylinder receives its motion from racks on the top edges of the carriage, but has its teeth cut away at one point to allow it to remain stationary during the return stroke. It is put into gear again by a rocking lever engaging a

pin on the rim of the cylinder; the lever receiving its motion from a cam. The cylinder is stopped by a friction brake actuated from a cam shaft close to one side of the machine, and driven by gearing from the flywheel shaft.

The position of the sheet on the laying-on board is gauged by a point projecting through it. This is worked from the cam shaft. The sheet is prevented from sliding too far by stops which move out of the way when the grippers have closed on the sheet; both these motions are obtained by a cam let into the end of the cylinder and worked from the cam shaft. The tapes which guide the sheet pass over jockey pulleys. The fliers for taking off the sheet are driven from the cylinder by gearing.

The inking arrangements comprise a ductor, in which are adjustable blocks to limit the spread of the ink, in contact with a roller driven by a ratchet from the second motion shaft. A ductor roller is oscillated by a cam between this and one of a pair of steel rollers, which, with two more intermediate rollers, finally distribute the ink to the two forme rollers. Some of these rollers receive an endwise movement, their bearings being rocked by an eccentric on the cam shaft. The five rollers are driven by gearing from the rack on one side of the bed.

The machine represented is one of numerous types and sizes; its speed per hour is 1,200 sheets of maximum size, 52 in. by 35·5 in., printed on one side; its weight is 6·75 tons.

1452. Printing press. Made by the Model Printing Press Co., 1893. M. 2497.

This is a small platen press patented in 1877, in which the forme is held in a nearly vertical position, and the platen, which is carried on a centre below, is forced against the type by depressing a hand lever, which by a toggle-joint gives the requisite final pressure. The inking is performed by two rollers carried by counterbalanced swinging arms. The ink is taken from a circular revolving distributing plate, over which the rollers travel before descending to the type, all the motions being derived from the movement of the hand lever.

1453. Printing machine. Presented by Josiah Wade, Esq., 1881. M. 1509.

This is a small platen machine patented by Mr. J. Wade in 1872, and is arranged for driving either by a treadle or by power.

On the flywheel shaft is a pinion, gearing into a spur wheel of five times its diameter. On the outer face of the wheel is a crank pin from which proceeds a connecting rod to a cast-iron lever, swinging on a frame which itself swings on a shaft at the floor level. This lever has on it a crank pin connected by a rod to the main framing of the machine. At the front side of the rocking frame is secured the "forme" of type, and on the top of the frame is carried the ink-distributing disc. Ink from the reservoir is conveyed to the disc by a ductor roller, and a pair of rollers, carried in a frame connected to the cast-iron arm, take ink from the distributing disc, and rolling downwards over the front of the forme, ink the type before each impression.

The platen that supports the paper is a ribbed cast-iron plate swinging on an axis at its lower edge. By a cam, formed on the inner face of the large spur wheel, two arms are moved upwards, swinging the plate forwards until the arms are perpendicular to its surface and acting as rigid struts. At this instant the swinging frame containing the forme is being slowly advanced by the motion derived from the rocking of the cast-iron lever which, using the connecting rod as a fulcrum, becomes a Stanhope lever, so giving a great closing pressure and a predetermined depth of impression. Should it be desired to suddenly prevent the platen closing on to the forme while running, this can be accomplished by moving a lever which carries with it the eccentric pin on which the connecting rod swings. The backward swing of the platen renders the correct placing and removal of the paper easy, and the platen cam gives a rest during one-third of its revolution while

the impression is being taken. The frisket is represented in this machine by a spring which holds the paper on the platen when passing beyond the perpendicular.

1454. Card printing machine. Contributed by C. L. Davies, Esq., 1861. M. 548.

This is a small rotary machine for printing address cards. The cards are piled in a box, so placed that the bottom card is tangential to two small cylinders. The bottom one is plain and covered with rubber to act as a platen, while the top one has the forme engraved on it in relief. The printing cylinder is rotated continuously by a handle, and tappets on each end of the cylinder engage two side links, which slide a plate that pushes out at each revolution the bottom card from the pile placed in the box; the slide is drawn back by india-rubber bands. An inking roller, driven from the platen cylinder by frictional contact, is supplied with ink by a distributing roller and ductor from an ink reservoir.

1455. Railway ticket printing and numbering machine. Presented by J. B. Edmondson, Esq., 1869. M. 1117.

This is one of the original machines for printing and numbering railway tickets, patented in 1848 by Thomas Edmondson.

The machine is worked by a hand lever, every double stroke of which prints and numbers a ticket. The blank tickets are stacked in a vertical box on one side of the machine, and at every stroke the lowest blank is pushed out upon a table or platen, which rises and so presses it against the printing forme fixed above.

After being printed, the ticket moves horizontally to the numbering apparatus. This consists of two printing wheels each numbered from 00 to 99, and moved one unit for each printing stroke of the hand lever.

For both the printing and the numbering, the ink is supplied by a saturated ribbon passing from a drum, underneath the type and the numbering wheel, and then being wound upon another drum; both drums are driven by ratchet wheels, and when all the ribbon is unwound, the return winding is quickly done by hand. The type squeezes the ink out of the ribbon on to the ticket, in the way so commonly followed in typewriting machines; this simple method of inking reduces the probability of smudging, when the finished tickets fall into the delivery box.

1456. Portions of Sir Rowland Hill's printing machine. Lent by Pearson Hill, Esq., 1877. M. 1928–9.

This machine was patented and publicly exhibited in 1835, but owing to the law at the time requiring that each sheet of newspaper should be stamped before printing, and the refusal of the authorities to allow the stamping to be done while the paper was in one continuous roll, the adoption of the rotary form of machine was delayed for many years, though the inventor, by pasting several sheets together, demonstrated the soundness of his scheme. Now all newspapers are printed from paper in continuous rolls from which each sheet is cut off as printed.

In the machine shown, there is a rotary printing cylinder to which the type is secured by mechanical means. To allow for the curvature, the type is wedge-shaped, but has a wide notch of uniform width into which sheet metal segments fit; these hold the type, and the ends of the segments or "binders" are themselves secured in notches formed in the galleys. Specimens of the special galleys, compositor's stick, and other peculiar details necessitated by the shape of the type are shown. The inking was performed by the series of rollers, one of which revolves in the ink trough and the last in contact with the cylinder, the intermediate rollers by successive transfer of the ink distributing it uniformly to the final inking roller. The platen cylinder is of the same diameter as the type cylinder, and connected with it by gearing.

The use of stereotype plates instead of type on the printing cylinder was also shown by the inventor, so that this machine contained the most important features of the modern high-speed rotary machines. The employment of a curved stereotype had, however, been patented in 1816 by Prof. Edward Cowper, who appears to have used them for printing wall-papers.

1457. Wall diagrams of printing machinery. Lent by E. A. Clowes, Esq., 1890. M. 2364.

These diagrams were prepared for a paper on "Printing Machinery," read by Mr. Clowes before the Institution of Civil Engineers in 1887.

Cowper's two-cylinder printing machine embodies the improvements patented by Prof. E. Cowper in 1818. It only prints on one side of the paper, but the output is doubled by the use of two platen cylinders. The flat forme is carried on a table, reciprocated by rack and pinion on friction rollers, beneath the two platen cylinders. Sheets are fed in at both ends, and the inking is performed by the now universal method of ductor roller, and inking and distributing rollers.

Cowper's perfecting machine was designed on similar lines to the last, but modified so as to print on both sides of the sheet in one passage. Model of this machine with a full description will be found in Nos. 1449–50, but the two following details are shown more fully by the diagrams:—

Cowper's drop-bar motion was the feeding arrangement employed, The sheet was so placed as to slightly overhang the feeding board, and at the right moment a roller on the extremity of the arm of a bell-crank lever, which was controlled by a cam, dropped on the paper and fed it between the tapes.

Cowper's parallel motion was introduced into the mangle-wheel mechanism by which the reciprocation of the table of the machine was performed. Beneath the table was arranged a vertical spindle terminating in a pinion which geared into a double rack with semi-circular ends; this rack was capable of sliding sideways between short guides fixed to the underside of the table, and was kept from binding by the hinged links, which constitute the parallel motion.

Hoe's six-cylinder machine was adopted by *The Times* in 1857. It was introduced by Col. R. M. Hoe, of New York, and resembled a vertical machine of Applegath's; it was not perfecting. It consisted of a large horizontal cylinder on which the types were fixed by column rules and screws; round the circumference of this were arranged six cylinders each about one-third of the diameter of the centre one. Between each of these were distributing and inking rollers, a laying-on board, tapes, flier, and a delivery board. Six attendants for feeding-in were required, and the maximum output was about 11,000 sheets per hour, as each sheet had to pass through twice. The working expenses were heavy, and the machine was soon discarded for the Walter press.

The Walter press is a rotary machine using curved stereotype formes, and printing on a continuous "web" or roll of paper, from which the separate papers are automatically cut off on delivery. It was designed and constructed in 1862–6 for printing the Times newspaper, and contains all the most important features of the modern high-speed newspaper machines.

From the paper roll the web passes over a tension roller, and then between damping cylinders, which are covered with blanket and supplied with wet steam. The water is squeezed in by two additional rollers, and the paper then passes round two platen cylinders of equal diameter, each supplied with inking rollers. In its course, the paper is printed on both sides and then passes to cutting cylinders, the knives on which cut off each sheet, with the exception of a tag at each side, which is left to enable the sheet to be drawn between two sets of tapes. Other rollers, whose speed is slightly greater than the paper, then tear off the sheets, which are carried by tapes up an inclined plane, and are delivered in a vertical position to an oscillating frame that places the sheets alternately on a delivery board on each side.

The Augsburg is a rotary web machine introduced in 1862. It prints on dry paper supercalendered, and has the "set-off" paper passing continuously through the machine, it being wound on and off a pair of drums below. There is a cutting apparatus, and also fliers that deliver the sheets on each side of the vertical.

The Victory is a rotary web machine, introduced in 1870 by Messrs. Geo. Duncan & Alex. Wilson. The paper from a roll at one end is led by guide rollers to the centre of the machine, on each side of which are arranged symmetrically the type and platen cylinders and inking apparatus. After printing, the paper is cut, folded (by an apparatus not shown), and deposited in two receiving boxes at the rate of 12,000 per hour.

The Standard machine was introduced by Messrs. J. Foster & Co., in 1880, and replaced a cylinder machine in which wedge types were employed. It is a rotary web machine, similar to the Walter press, but the paper, after being cut, passes horizontally to a folding apparatus (not shown).

The Whitefriars is a rotary machine designed for printing periodicals, with or without illustrations, and was brought out by Messrs. Pardoe & Davis in 1872. The paper may be used from the web (as shown), or in single sheets, fed in by a drop-bar motion. The roll of paper is supported in an independent frame, that contains also the cutting cylinders, so that the paper is supplied in sheets in both cases. It is a perfecting machine with two stereotype cylinders; the plates are cast flat, and afterwards bent to the requisite curvature.

The Hoe rotary web machine was introduced by Col. R. M. Hoe, in 1873, but has since been repeatedly improved. The arrangement of the machine is very compact, owing to the roll of paper being placed above the cylinders. One platen and two type cylinders, with the ordinary inking arrangements on the outside, are placed in the same horizontal plane, while the second platen cylinder is below, and to avoid set-off is made three times the diameter of the first. The paper, after being printed on the two sides and partly cut, is carried by tapes to a drum, whose circumference is equal to the length of the sheet, upon which nine papers are successively wound and cut. They are then stripped off together and delivered in a vertical position against the flier, where they are retained by an air blast till the flier swings down and deposits them on the delivery board.

The Graphic is a two-feeder single-cylinder machine, introduced by Messrs. B. W. Davis & J. Parsons in 1874, for printing high-class illustrations and bookwork. It prints from a flat forme, and on one side of the sheet only, but uses a cylindrical platen. It is fed from both ends with single sheets, which, after being printed on one side, are delivered face upwards upon boards vertically over the feeding boards. The reciprocating bed which carries the forme and ink distributing table is driven by a crank and connecting rod, the travel being doubled by a spur wheel, which rolls on a fixed rack below and engages with one fixed to the table. The sheets are carried by tapes, and the inking and distributing arrangements closely resemble those of Cowper and Applegath.

The Ingram is a rotary web machine, introduced by Messrs. W. J. Ingram & J. Brister in 1876, for printing illustrated newspapers. The second stereotype cylinder, from which the illustrations are printed, is of large diameter, so as to reduce the curvature of the plates, and is fitted with double the usual number of distributing and inking rollers. The paper passes from the roll over the first platen cylinder, where the letterpress is printed, then through two rollers and under the large platen cylinder revolving at the same peripheral speed. In the diagram the diameters of the cylinders are in the ratio of 2 : 3, so that there are two stereotypes of the letterpress on the first cylinder, and three of the illustrations on the second. The paper after being printed is cut between two cylinders and passes to a folding apparatus (not shown).

The Davis perfecting machine was introduced in 1884, and is a simplified and improved form of the Cowper, printing from flat formes, and having two equal platen cylinders above. Tapes are used to some extent in

conducting the paper, but the employment of grippers greatly reduces the amount of tape required. The table is driven by a crank motion as in the Graphic, and the platen cylinders are driven by a rack on the table.

1458. Copper-plate printing press. Formerly the property of James Nasmyth. Received 1899. M. 3066.

The press shown is of the construction now usual, and consists of two cast-iron adjustable housings, carrying a roll 6 in. diam. below and a roll 2 in. diam. above. Between the rolls is a travelling wooden table faced with iron plate, which rests on the lower roll and also upon four loose supporting and guiding rollers. The inked and cleaned plate is placed on this table and covered with a damped sheet of paper upon which is placed some blanketing, the whole is then passed between the rolls while the upper roll is being turned by a long double-ended hand-lever.

The arrangement gives a powerful squeeze without subjecting the plate or table to any bending stress.

1459. Copper-plate printing press. Presented by the Exors. of the late George Wallis, Esq., 1906. M. 1509A.

This is a small press of the kind used for printing from an engraved copper-plate, and was specially designed and patented in 1860 by Mr. Wallis for preparing the plates in his autotypographic process (*see* No. 1466).

A lower roll, driven by hand-wheel and worm gearing in the ratio 80 : 1, is in fixed bearings in vertical housings within which slide the brasses of an upper roll driven from the lower one by spur gearing. Between the rolls is a flat table carried in horizontal guides which can spring slightly vertically. The soft metal plate is placed over the drawing, &c., from which the impression is to be obtained; they are laid together on the table which is passed through the rolls by frictional contact. The adjustment of the upper roll to obtain any desired pressure is made by a screw in each housing having graduated hand-wheels with a spring index.

1460. Specimens of woodcuts. Received 1859–63. M. 1774A.

Several examples are shown of engraved wood blocks for printing woodcuts or playing cards. Before the invention of movable type each page of letterpress was printed from blocks engraved in this way, but these examples, which are chiefly from the Continent, are more recent, dating probably from 1600 to 1800, as given on the cases. The block, engraved by Sir J. D. Linton, for printing the Certificate of Merit for the International Exhibition of 1862, is also shown as an example of later work.

1461. Printer's composing stick. Presented by Charles Goulden, Esq., 1878. M. 1647.

This example was discovered in an old printing office at Canterbury, and is believed to have been made about 1750; it is entirely of mahogany and takes lines 5 in. long. Composing sticks for large type are still made of wood, but the small ones are now always of metal and generally have an adjustable metal slide to vary the length of the line.

1462. Logotypes. Lent by the Trustees of the British Museum, 1899. M. 3085.

These are a selection of duplicates from a complete fount of this arrangement of type preserved at the British Museum. The types differ from those ordinarily used in that the fount comprises a large number of complete words in addition to individual letters. The system was patented by Mr. Henry Johnson in 1778–80, and Mr. John Walter was so impressed with its merit that he purchased the patent rights. After reducing the symbols to 1,500,

he adopted the system in 1784 at his "Logographic Office" in Printing House Square, and in 1785 in this way published the "Daily Universal Register," which in 1788 became the Times newspaper.

The objections to logotypes were: the great size of the compositor's case, the difficulty in casting, and the delay experienced in "justifying" a line ending in a logotype. To overcome the latter objection Mr. Matthew Beniowski in 1846 introduced a system of logotypes in which the single types were bound together by varnished tinfoil.

These systems have both disappeared, but in modern founts such combinations as ff, ffi, ffl, known as ligatures, are still cast together, for the reason that if separate they would occupy so much space as to appear unsightly.

1463. Formes with stereotype plates. Lent by Harvey Dalziel, Esq., 1893. M. 2496.

The specimens comprise two formes, one containing an ordinary electrotype and two stereotypes, and the other containing the same two plates produced by a stereotyping process introduced by Mr. Dalziel, which is stated to be equal to electrotyping while much quicker.

The examples also show two methods of holding the stereotypes when in the printing machine. In the first forme the ordinary method is shown, in which the electrotype is pinned down on a wood mount, whilst each stereotype is fixed on four lead blocks by brass catches on their edges which clip its sides; the lead blocks are separated by three wood packing pieces, which must be different for each different size of plate. In the second forme, each stereotype is mounted on two cast-iron triangular blocks which become, when in position, the adjacent sides of a rectangle. Projecting ledges on the blocks clip the edges of the stereotype; by altering the thickness of the diagonal packing piece a pair of blocks can be made to clip stereotypes varying considerably in dimensions.

1464. Specimens of "nature printing." Contributed by the Society of Arts, 1858. M. 290.

Nature printing is a combined printing and embossing process, introduced by Dr. F. Branson, of Sheffield, in 1851. He made a mould in gutta-percha from a fresh fern, or similar natural object that could be placed on a flat surface, and from this obtained an electrotype plate that was used for printing from, the plate being correctly coloured by hand before impressing. The specimens show that the prints came out in high relief and were very detailed. To reduce the cost, brass castings, moulded from the gutta-percha pattern, were afterwards substituted for the electrotype plates.

Eight specimens of the work are shown, as well as one of the gutta-percha moulds, and cast-brass plates used in their production.

1465. Specimen of colour printing. Contributed by G. Baxter, Esq., 1860. M. 501.

This is a good example of colour printing by a process patented by Mr. Baxter in 1858. At that time the practice was to print engravings and then colour them by hand, a method both slow and expensive. The improvement consisted in applying the colours successively by block printing. Marginal dots were left by the first plate, to be used as register marks for securing the true superposition of the several colouring blocks.

Chromo-lithography has superseded this process, being cheaper and quicker through dispensing with cut blocks.

1466. Specimens of autotypography. Presented by the Exors. of the late George Wallis, Esq., 1906. M. 1509B.

Autotypography was a plate-printing process in which the plate was prepared directly from the artist's drawing, as patented in 1860 by

Mr. Wallis. The active ingredient in the ink was a bichromate salt which, when mixed with organic matter, saturated, and exposed to light, darkens and hardens the latter owing to a reduction to chromic oxide taking place. Mechanically hard material was also used in the ink or dusted on afterwards. A relief is thus obtained hard enough to indent a plate of Britannia metal, copper, or German silver by passing them together through a roller press (*see* No. 1459). The plate is subsequently used to print from as in the copper-plate process. Drawings made on gelatine with bichromate ink, a plate, and finished prints are shown.

Two pieces of porcelain ornamented by the "bat" process from designs reproduced in this manner are also shown. In bat printing the impression is transferred to a bat of gelatine or glue, by which it is printed on the glaze in oil or tar. Enamel powder is then dusted over the print and, adhering to the oiled surface, is fixed by firing the porcelain at a low temperature.

TYPEWRITING MACHINES.

Typewriting is the art of printing legible characters one by one on paper by mechanical means; it thus stands midway between ordinary writing and printing, lessening on one hand the delicate mental and muscular labour that so greatly reduces speed, and on the other hand obviating the necessity for heavy machinery.

As early as 1714 Henry Mill patented a machine which he "had brought to perfection at great paines and expence," for impressing letters on paper as in writing; no drawings or particulars are, however, given. In America the first record of any kind is the patent granted in 1829 to William A. Burt for a "typographer." All record of this machine perished in a fire at Washington in 1836. In 1833 Mons. X. Progin, of Marseilles, patented a "ktypographic machine or pen," which is remarkable as being the first to embody the type-bar principle. The body of the machine was moved over the paper in two directions, the motion being fixed by pawl and rack, and controlled by guides. At the British Association meeting at York in 1844 there was exhibited by Mr. Littledale, of that city, an apparatus by which the blind could read and write, a motive that seems to have stimulated several other early inventors. His machine had a set of wooden type in a slide, so arranged as to be brought one by one beneath a hammer; the paper was at each stroke embossed with a character and also moved sideways. Patents were taken out by Charles Thurber, of Mass., U.S.A., in 1843 and 1845 for a "chirographer" or "machine for printing." It had a horizontal wheel, in whose periphery were 44 holes, each carrying a rod with a steel type on its lower end; the wheel had to be rotated till the particular type was over the printing point. This machine first embodied the idea of a platen cylinder for the paper, but both its longitudinal and rotary motions had to be performed separately. In

1846 Benjamin Vickers patented, as a communication from abroad, a machine in which the operation of writing was imitated by combined vertical and horizontal motions that caused a pencil to trace out the character required. These motions were obtained from cams on a revolving shaft, and the paper was moved along by the same lever that put the clutch of the particular cam into gear. Pierre Foucault, a pupil of the Institution of the Blind, at Paris, patented and exhibited in 1849 a machine with a curved keyboard; the rods with type on their extremities slid in radial grooves in a vertical plane to a common printing point, there embossing the paper, which could be advanced after each letter by a rack and pawl. At the Great Exhibition of 1851, besides Foucault's machine, there was also exhibited the "typograph" of William Hughes, governor of the Manchester Blind Asylum; one of them is preserved in the Museum (*see* No. 1467). About this time also Sir Charles Wheatstone, while engaged in perfecting his dial telegraph, made a working typewriter, and between 1855 and 1860 he constructed six different machines, three of which are preserved in the Museum (*see* Nos. 1469–71). In America, between the years 1847 and 1856, Alfred E. Beach, editor of the "Scientific American," invented several machines; the first printed on a sheet of paper carried in a frame provided with a weight for running it, and controlled by a rack and pawl: the finger keys were connected to the type-bars, arranged in a circle, and there was also a line-spacing key. A second machine, that he exhibited in 1856, had a set of radially arranged double levers like tongs which closed together and, as their ends formed pairs of dies, embossed the required character on a strip of paper, drawn through the machine by a clockwork escapement controlled by the operator. Beach's invention was followed in 1857 by that of Dr. S. W. Francis, of New York, whose machine embodied a pianoforte keyboard, with keys connected by a kind of trip gear with type-bars arranged in a circle, and striking at one central point. The inking was done by a ribbon, while the paper was drawn from right to left by a spring released by a detent after each impression. In 1866 John Pratt, an American residing in London, patented an important machine in which the possibility of producing writing by mechanical means faster than by the pen was practically shown (*see* No. 1473). The success attained by Pratt drew the attention of Messrs. C. L. Sholes & C. Glidden to the subject, and by the end of 1868 a machine was finished. Some 20 or 30 improved machines were made by 1873, when it was decided to entrust the manufacture on a large scale to Messrs. E. Remington & Sons, who in 1875 placed the Sholes & Glidden typewriter on the market (*see* No. 1474). In 1878 the Remington machine with two type on each bar was brought out, and since then the use of typewriting machines has regularly increased, and their manufacture and improvement have received continuous attention.

Typewriting machines may now be classed under three heads, viz.: index machines, type-wheel machines, and type-bar machines.

Index machines have an index plate and pointer, by means of which the desired letter is brought over the printing point and then usually depressed by a knob; the paper is placed on a platen cylinder, which has both endwise and rotary motion. Such machines are simple, cheap, and portable, but their speed is slow and insufficient for commercial purposes. The Hall, the first machine of the index class, was patented in 1881 (*see* No. 1477), and was followed in 1884 by the Columbia (*see* No. 1479); the latest examples of this class are remarkable for their simplicity and compactness.

Type-wheel machines have the type arranged on the periphery of a wheel or shuttle. There is a keyboard, and by the depression of a key a combined vertical and rotary movement is given to the wheel, so bringing the corresponding character to the printing point, where it is struck by a hammer. To this class belonged Pratt's typewriter of 1866, and also the Crandall patented in 1879, but the Hammond (*see* No. 1486), introduced in 1884, is the best known modern example of this construction, which particularly lends itself to high speed.

Type-bar machines, however, embrace by far the largest number of modern typewriters. All of these have keyboards, and the type are on pivoted bars, arranged in a circle or segment of a circle, and strike to a common printing point; the inking is usually done by a ribbon, but in some machines by a pad. To this class belonged the machines of Francis and Beach, while many examples of modern type-bar machines will be found in the collection. Some of the later machines give "differential" spacing, by which the feed after a letter is printed varies with the width of the character, a modification that somewhat improves the appearance of the work produced.

1467. "Typograph" for the blind. Contributed by Mrs. M. R. Wild, 1862. M. 768.

This machine, for enabling the blind to "record their thoughts on paper with mechanical regularity," was invented in 1850 by Mr. William Hughes, governor of the Manchester Blind Asylum; it was awarded medals at the Exhibitions of 1851 and 1862. The machine was first designed for using embossing type, but was subsequently modified for ordinary printing by the use of carbon paper, as in the present example.

There are 43 type carried in vertical holes in a horizontal wheel, which is provided with a dial plate of raised characters to enable the blind person to distinguish them. The wheel is rotated by the right hand till the correct character is reached, and then the lever is pressed down by the left hand on to the type beneath it; this movement also locks the type-wheel in position. The type springs up again on raising the lever, and the whole type-wheel is at the same time fed along a cross slide by a ratchet gear that gives the spacing. Line-spacing is effected by a screw head in front, which pushes up the frame containing the paper one space for every complete turn.

1468. Typewriter for the blind. Presented by J. Martin, Esq., 1862. M. 2933.

This machine, introduced in 1862, is similar to that of Mr. Hughes (*see* No. 1467). There are 37 type, set with pin points and mounted in a wheel, the underside of which acts as a plate spring to lift the type. Letter-spacing is given by a rack, and line-spacing by a ratchet wheel on a roller which feeds in the paper. The type perforates the paper, and on the lower side leaves a series of burrs, which can be read by the sense of touch.

1469. Typewriter. Wheatstone Collection, 1884. M. 1552.

This and the two succeeding machines were designed by Sir C. Wheatstone, for the rapid printing of telegrams.

The machine, made in 1851, has a keyboard somewhat resembling that of a piano, and prints on a paper strip or tape; 29 of the keys are for printing capitals, the remaining one being a space-key. The type are mounted on flexible tongues of metal resembling the teeth of a comb; the comb is at the top of the machine and is segmental, the teeth radiating from a common centre to which the comb is pivoted. There is a small hammer above the comb and over the printing point. Each key forms one arm of a bell-crank lever, so that when depressed it forces forward the other arm into a horizontal slotted plate, connected with the comb and so arranged as to slide the latter sideways until the particular type is under the hammer, which then delivers its blow. The comb is after each impression brought back to a zero position by two springs. As the key rises, a friction-grip catches the strip of paper and draws it forward through the space of a letter. The type are inked between each impression by a segmental pad caused to vibrate between the type-comb and the small well of ink. Both hammer and pad are actuated by a bell-crank lever attached to a bar running under the whole of the keys, by any one of which it may be depressed. Under the machine is a drawer to contain the reel of paper, which is mounted on friction rollers.

The letters had to be kept small, as the extremities of the comb require a considerable travel of the bell-crank lever to bring them into position, so that the keyboard occupies considerable room.

1470. Typewriter. Wheatstone Collection, 1884. M. 1556.

This machine (1856) is an advance on the previous one, in that it has a "change of case," *i.e.*, it can print both capitals and small letters.

The comb is still retained, but forms part of the surface of a cylinder whose axis is the centre of a swinging segmental plate containing cams, by means of which it can be swung into various positions. On an elevated keyboard are 26 round keys forced upwards by springs; each key carries a small pin on its side that engages with a separate cam groove in the segmental plate. By causing the keys for the symbols furthest from the printing point to act near the centre of the plate, it was possible to make the grooves nearly alike. Change of case is accomplished by mounting on the segmental plate a second comb that is brought beneath the printing hammer by sliding it along the arbor, a key being provided for this purpose. The paper, folded by means of an apparatus shown, is placed on a cylinder; each key, when depressed, causes the cylinder by a pawl and ratchet wheel to partly revolve. Line-spacing is accomplished by the cylinder sliding along its axis, a rack below engaging with a spring flange on the cylinder acting as a cam. The type are inked by means of an annular inking pad that encircles the cylinder, and is rotated by a friction wheel.

1471. Typewriter. Wheatstone Collection, 1884. M. 1551.

This machine, made between 1855 and 1860, is the final form tried by Sir C. Wheatstone.

It has the piano keyboard of his first, the paper cylinder and change of case of his second. The small middle key in front is for change of case and two side keys give spacing between words. It would now be considered that the keys are too heavy, and that the inking arrangement is imperfect, but the machine remains one of the earliest successful typewriters.

1472. Pratt's original typewriter. Lent by the Yost Typewriter Co., Ltd., 1903. M. 3277.

The leading details of this early type-bar machine were patented in 1864 by Mr. John Pratt, of Alabama, U.S.A., and the typewriter itself was constructed by him, with the collaboration of a pianoforte manufacturer and a scientific instrument maker, at Glasgow, in 1865. It contains some features of the 1847 machine of Dr. A. E. Beach, of New York, and of that of 1849 by Pierre Foucault, of Paris, but there is no evidence that Pratt was acquainted with their work.

The single case of type is formed on the upper ends of 26 rods, arranged to slide in slots on the sides of a truncated cone, the apex of which is the common printing point; each rod has a projecting lug by which it is pressed downwards by a ring weight, common to all, and can also be forced upwards by its key-lever, connected to it by intermediate levers arranged to secure uniform touch. The key-levers, including a spacing key, are grouped as in a piano keyboard, and each communicates by a vertical pin and lever with a transverse bar underneath. This bar has attached to it a vertical rod which actuated a ratchet wheel that gave the letter and word-spacing motion to the paper carriage on the under side of the lid which, when writing was being done, would be closed down. The paper was held, by a spring clip, in contact with carbon paper, and the small flat carriage contains a slide at right angles to its own guides. The return of the carriage, on completing a line, was accomplished by a lever, on the under side of the lid, having a knob projecting above through a segmental slot; line-spacing was obtained by pressing a similarly situated knob. Pratt ultimately abandoned this typewriter in favour of his type-wheel machine (*see* No. 1473.)

1473. Pratt's typewriter. Received 1893. Plate VIII., No. 3. M. 2524.

This typewriter was made and patented by Mr. John Pratt in 1866. The 36 symbols used are mounted in three rows of 12 each on a vertical type roller. Against this roller a hammer strikes, so that an intervening paper with a carbon sheet receives the impression of the type. The paper is carried in a vertical frame which moves automatically after each letter is impressed, but the word spaces are given by partially depressing any one key. The movement of the type-wheel and of the paper-holder is caused by the action of two springs, which at the completion of each line are wound up by depressing a large key. At the lower end of the type spindle is a circular case from which any one of the 12 stops will be projected by depressing its key, but for the second and third rows of symbols in the type-wheel, the wheel is lifted at the same time. Pressing down any letter key sets in position a stop for the type-wheel and delivers a uniform blow with the hammer, the rotation of the wheel being accomplished by the spring.

1474. Sholes & Glidden typewriter. Presented by Lady Brassey, 1881. M. 1512.

This is one of the original machines invented by Messrs. C. Latham Sholes & Carlos Glidden, between 1867 and 1873. It was manufactured and introduced by Messrs. E. Remington & Sons, of Ilion, New York, in 1875, and was a sound practical machine, but only wrote in capital letters.

It is a type-bar machine, with the levers hanging vertically round a circular opening in the top of the frame, so that the type strike upwards at the common centre. There are 44 keys, connected by horizontal levers and

vertical wires to the same number of type-bars. Each bar has but one character, so there is no change of case.

The platen cylinder is supported in a carriage, that slides on a rod at the back and is supported by a wheel in front. The paper, which may be of any length but not more than 8·25 in. wide, passes under the platen cylinder, with which it is held in contact by two rubber bands passing round rollers on the carriage. To inspect the work, the carriage can be swung upwards round the guide rod, which acts also as a hinge. The carriage is continuously pulled to the left by a spring, the motion being checked by a rack attached to the carriage, and engaging with two vibrating detents that release one tooth with each character printed. At the end of a line the carriage is returned and the cylinder slightly rotated by a cord attached to an external lever at the right-hand side; this return movement also winds up the feeding spring.

Inking is done by a wide ribbon, interposed between the paper and the type. The ribbon stretches horizontally over the top of the framing from a spool on each side, and is slowly wound alternately from one to the other by the motion of the machine; the reversal of the winding, when either spool is emptied, is performed by a hand-moved clutch.

The arrangement of this keyboard has since been adopted in nearly all typewriting machines, and is now known as the "universal." In front of the four rows of keys is a long space-key, for moving the carriage at the end of each word.

1475. Writing ball. Presented by P. Jensen, Esq., 1906. M. 3441.

This early form of typewriter was patented in 1870 and 1875 by the Rev. R. J. M. Hansen, superintendent of the Royal Institution for the Deaf and Dumb at Copenhagen, and manufactured in that city to a limited extent.

There are 52 type rods, including one for spacing, arranged, so as to be easily fingered, on a portion of a sphere having an insulated cover and let into a hinged frame by which it can be lifted out of the way; the whole is supported by a cast-iron base. Each type rod has a character, cut at its lower end and engraved on a key above. Each is kept in the raised position by a helical spring and is prevented from rotating by a portion of the stem being squared. All radiate to the printing point at the centre, where the paper, with a carbon sheet over it, is clamped on a carriage with a shrouded rack on the underside to give letter-spacing. The spur wheel which gears into it has a feather and slides on a shaft which is driven by clockwork; on the shaft is an escape wheel controlled by an electro-magnet, the circuit of which is closed every time a key is depressed. The paper carriage rolls on rails on a frame which slides on guides at right angles to the rails to allow of line-spacing. For this purpose there is on the paper carriage a hinged spring tongue with an inclined face which at the end of a line comes in contact with fixed pins on a bar, and in doing so the carriage is forced up a line-space carrying with it the frame.

Subsequently a mechanical means of letter-spacing was devised and the machine brought into a more compact form, but by that time a type-bar machine was on the market (*see* No. 1474).

1476. Remington typewriter. Contributed by Lieut.-Col. A. H. P. Stuart-Wortley, 1880. M. 1489.

This is a "No. 2 Remington," a form of machine that was first brought out in 1878. It is a development of the Sholes & Glidden machine (No. 1474), from which it differs chiefly in having a change of case, as well as in a few of the details. By these alterations it became a complete typewriter suited for general work, and its adoption in the commercial world soon rapidly extended.

There are 40 keys, each actuating a separate type-bar, but each bar has two characters on its extremity so that, omitting the two change-case keys,

76 characters in all can be printed. The change-case keys, by means of a lever, slide the platen cylinder to and fro in its carriage, and so alter its position with reference to the printing point of the type-bars, thus determining which of the two characters on each bar will be impressed. For raising the carriage, in order to inspect the writing, a handle is provided in front; this is also used to draw the carriage back, and to turn the platen cylinder round by the amount required for a fresh line.

1477. Hall typewriter. Presented by Major W. G. A. Bedford, M.B., R.A.M.C., 1899. M. 3070.

This machine is of the index type, and was patented in 1881 by Mr. Thomas Hall, of New York, who had been working for some years at the problem of producing a simple typewriter.

The fount is formed by a square sheet of rubber, from the lower face of which the characters project; it is carried in a frame free to slide horizontally in any direction, but prevented from rotating. The index is in a similar frame above, provided with holes for each character; by a handle, carrying a key fitting these holes and connected to the lower moving frame, the desired character is placed over the printing point and then depressed. The inking is done by a saturated textile sheet, arranged between the rubber type and the paper, a mask with a single hole at the printing point preventing accidental contacts. The paper is carried on a platen cylinder, capable of rotary or longitudinal motion, and the feed is performed by an escapement, worked by the printing handle and gearing into a cylindrical rack. The line-spacing is given by a separate key which moves a ratchet wheel on the paper roller.

1478. Hammonia typewriter. Presented by C. A. Palmer, Esq., 1904. M. 3343.

This typewriter, patented in 1884 by Mr. H. A. H. Guhl, is of the index class, and is intermediate in character between the earlier machines for the blind (*see* No. 1467), and the dial machines (*see* No. 1477).

The fount of 45 characters is on the edge of a thin straight blade provided with a handle and guided in a frame sliding on a bar at the back. The desired character is brought to the printing point by sliding the blade till an index pin, projecting from the sides of the blade, is over the corresponding character on a fixed tablet; this pin also assists the alignment by fitting between teeth on the tablet. Letter-spacing is obtained from a ratchet on the frame, which is forced down by the blade into gear with a stationary rack. The platen is a narrow strip of soft metal, over which the paper is fed by two rollers, one of which has a ratchet lever for giving the line-spacing; the top roller can be released by a lever at the left side when the paper is to be inserted. Inking is done by a ribbon, which is fed along by a ratchet at each depression of the blade.

1479. Columbia typewriter. Presented by A. E. Morton, Esq., 1895. M. 2901.

This is a form of dial machine, patented in 1884, and used with considerable success, but, in common with all such machines, it has, where speed of writing is required, been unable to compete with those having a keyboard. It was, however, an exceedingly light typewriter, and turned out good work, well aligned, and with correct differential spacing.

The 72 characters are arranged on the edge of a vertical metal disc or type-wheel, carried loosely on a horizontal arm, and provided with a handle by which the wheel is turned and the arm depressed in the act of printing. Above the axis is a dial, the index of which, double-ended and driven directly by the type-wheel, indicates the letter that will be printed when the handle is depressed. The inking is done by a saturated circular pad swinging from under the disc as the latter is depressed, so leaving the type inked. The

carriage has a single rubber-covered roller of ·4 in. diam., and a sheet-metal clip; an adjustable margin stop and a bell are arranged in the body casting, and an eight-toothed wheel gives the line-spacing. On the carriage is a long and finely pitched rack, into which engages a pawl carried by a lever driven by a cam plate on the back of the type-wheel. This cam determines the amount of feed for each letter, which varies from one to three teeth, according to width; the cam is somewhat simplified by the grouping of the symbols.

1480. Fitch typewriter. Received 1892. M. 2454.

This machine was patented by Mr. E. Fitch in 1886–90. The 26 keys employed actuate the same number of type-bars, but by a change key at the left, each lever can print three different symbols. The type is normally at rest in a row at a height of ·3 in. above the paper roller, and as a key is depressed the corresponding lever springs downwards and slides along an inclined guide into a central notch which steadies it while printing. On entering this notch the type presses upon a small inking roller, which then swings aside and allows the inked type to reach the paper. The return of the type is secured by a spring assisted by the guiding action of the adjacent levers. The paper is held in a metal scroll in front, and is pressed upon the printing roller over which it passes to a similar holder behind, so that the writing is visible while in progress.

In the machine shown the characters resemble handwriting and are connected, but printing symbols may also be employed.

1481. Waverley typewriter. Lent by the Waverley Typewriter Co., 1895. M. 2902.

This machine is constructed under the patents of Messrs. Higgins & Jenkins of 1889 and 1892. It has 76 type-bars, each of which carries only one character. The keyboard has only 38 true keys, each actuating a lower case type-bar, or when the upper case key is depressed, the corresponding upper case type-bar.

The inking is performed by a ribbon, which by a double fold returns parallel to itself. The fold of the ribbon is carried by a swinging arm, which lowers it on to the paper when a type-bar is descending; at all other times it is so far above the paper that the writing is completely visible. The carriage is pulled along by a coiled spring, checked by a rack escapement in the usual manner, but the teeth of this rack are of but one half of the usual pitch. Differential spacing is secured by allowing the carriage to move past a single tooth after printing a narrow letter, and past two teeth for a wider letter, while for the widest letters the feed is three teeth. This variation of the feed is attained by arranging that, for the wider letters, each key lever lifts one or both of a pair of small bars which act as packing pieces and reduce the travel of the escapement when not lifted. In front of the keyboard is the usual space key, but it is so connected that this key and that of the final letter of a word can be simultaneously depressed, thus combining the spacing with the writing movement.

1482. English typewriter. Lent by the English Typewriter Co., 1891. M. 2417.

In this machine there are 29 type levers arranged in a circular arc, convex to the operator. Each lever carries three symbols, but the one impressed depends upon the distance of the paper roller from the lever centre, and this is determined by two keys which can be locked down when necessary, but in the normal position the ordinary small characters will be printed. The paper is carried under and over the roller at the back, the printing being done on the top surface, which is visible to the operator. The ink is conveyed by a narrow ribbon which is wound from one reel to another

by the motion of the keys, passing in its course over the spot where the type strikes. The movement of the paper to the left, as each letter is printed, is obtained by the use of a spiral spring contained in a drum round which the hauling chain winds. A pin can be inserted into any one of a series of holes in this spring box, and so cause a bell to sound when the desired length of line has been reached.

1483. Gardner typewriter. Received 1897. M. 3009.

This typewriter, patented by Mr. J. Gardner in 1893, is an attempt to reduce the size of such machines, and although it prints 84 symbols, has but 14 keys and two change-case keys. The change keys control six cases, and, in working, the left hand is continuously adjusting these while the right depresses other keys. As both hands are used in printing a single character, the manipulation of the machine is difficult.

The type is arranged in six rows on a vertical rubber-faced cylinder, which is inked by two saturated inking rollers. The paper is carried by a small carriage from which it passes upwards as printed; the carriage is fed along by a rack driven by a pinion on the spring box; on the rim of the box is fixed the escapement. Printing is performed by a small rubber-tipped hammer, at the back of the paper, which, after a key is depressed, forces the paper against the printing cylinder; an intervening mask prevents more than one character being printed at a time. Which row of type shall be opposite the printing hammer is determined by the two change-case keys; one moves horizontally in contact with a pawl that fits against teeth upon it, and determines three elevations of the type cylinder, while a vertically moving key engages with other teeth that fix three intermediate positions for the cylinder. When the row is thus settled, the correct rotation of the cylinder is performed by the key depressed, which partly rotates a horizontal shaft on which is a crown segment gearing with a long pinion on the type cylinder, and then works the hammer. A locking lever is introduced which by fitting into the teeth of the long pinion secures precision in the angular position of the cylinder.

1484. Lambert typewriter. Received 1907. M. 3488.

This machine, which has features of the type-wheel class, was patented in 1896–8 by Mr. F. Lambert.

The fount of 84 characters is arranged in three concentric staggered rows on a spherical surface connected by an arm and a clutch with a disc on which 28 buttons, each marked with three characters, are arranged in the same order. The disc is carried on a ball-ended rod so that it can tilt in any direction, but is prevented by a pin from rotating. Attached to the ball by a spring is a cap which bears against the centre of the disc on which are radial corrugations corresponding in number to the buttons. A plane passing through the centre of the ball touches the buttons so that when a button is depressed there is no moment tending to rock the disc, and as the corrugation gives two points of support it always tilts in one particular path. The distance it is allowed to tilt is determined by a pin in line with the axis engaging spaces in one of three stepped internal rings on the upper side of the type surface. The pin can be depressed by a cam and lever so as to engage any one of the three rings, so giving two changes of case. By displacing the disc slightly, relative to the type surface, sloping letters can be obtained. The ball and the guide pin are both in a bracket carried by links which permit the whole to be depressed to bring the selected type against the anvil, the other type being meanwhile shielded by a mask which has on its upper surface an inking pad in contact with the type. The disc with all its parts is hinged so that it can be turned back. The depression of the disc actuates the escapement which gives letter-spacing. The carriage is free, being propelled by a coil spring. Line-spacing is given by the usual ratchet feed. The machine with its case weighs 8·5 lbs.

1485. North's typewriter. Lent by North's Typewriter Manufacturing Co., 1898. M. 2734.

The original North machine was introduced in 1893 by Col. North, who purchased the works of the "English" Typewriter Co. (*see* No. 1482) for its manufacture; the example shown is, however, an improved form brought out in 1898.

The machine has 39 ordinary keys and the same number of type-bars, but, by a single change of case, the number of symbols printed is 78. The bars stand vertically in an arc, concave to the operator and behind the carriage; long bearings for the joints are secured by arranging them at four different levels. The motion from a key is transmitted by a single lever to a vertical compression-rod connected with a short arm on the back of the type-bar.

The carriage is constructed with open ends, so that any width of paper can be inserted, and as the roller is 9·6 in. long the machine can use "brief" paper without leaving excessive margins. The carriage frame is supported on balls, and the upper portion of the carriage, in the slight movement required for change of case, also travels on balls.

The margins are determined by pegs that can be inserted in a perforated bar in the front, while an adjustable stop on the carriage provides means for regulating the striking of the signal bell. The feed is ·1 in., and is given by the usual double detent, attached to the carriage, which is propelled by a spring within a winding drum.

The inking is done by a narrow ribbon, which only hides the last character impressed; the bar leading the ribbon from the reels to the printing point is hinged, so that it can be lifted clear of the paper when required. The outer end of the ribbon lever is adjustable, so that the whole width of the ribbon can be ultimately utilised.

1486. Hammond typewriter. Lent by the Hammond Typewriter Co., 1907. M. 2742.

This machine, introduced by Mr. J. B. Hammond between 1880 and 1884, is like Pratt's (*see* No. 1473) of the type-wheel class, but differs from it in mechanical construction.

The keyboard is of the Universal pattern with 30 keys, which, with two change-case keys, give 90 characters. The type-wheel takes the form of a shuttle, a curved piece of vulcanite on which three rows of characters are in relief. This shuttle may be quickly replaced by another so that a variety of founts, necessitating corresponding "language plates," may be used in one machine. A steel rib, fixed on the back of the shuttle, slides horizontally in a slot in a circular cast-iron anvil situated at the centre of the machine. The anvil is centred on a vertical shaft which can be raised by the change-case key till the required row of characters is at the printing level.

The depression of a key to print a character lifts a corresponding spring index-pin which is the same angular distance as is the character from one side of the normal position. The key also causes a bell-crank lever, resting on one half of the bank of keys, to actuate an arm engaging with the shuttle and oscillating it till the arm is stopped by the index-pin. The key then releases the spring-actuated hammer, whose blow, being independent of the operator's touch, is invariable and may be adjusted for manifolding and other work. The blow of the hammer is distributed over the character by a rubber band while a disappearing shield or thin metal mask with a central hole is provided which prevents the paper touching any other than the intended character. The shuttle returns to the normal position ready for the next impression. The depression of the key also releases the escapement of the carriage; the paper is held in a cylinder of wire netting, line-spacing being given by two rollers. The inking ribbon is of two colours, purple and black; the writing is visible.

The machine shown is a No. 12, which writes a line 8·5 in. long.

1487. Yost typewriter. Lent by the Yost Typewriter Co., 1904. M. 2443.

This is a developed form of the machine invented by Mr. G. W. N. Yost in 1887, and commercially introduced in 1890.

It has a separate key and type-bar for each of the 85 symbols employed, and there is a circular inking pad, against which the type rest when not printing; this pad absorbs sufficient ink for several months' work. The carriage is above the framing, and has the usual paper roller on a swinging attachment, so that the work can be lifted for inspection; there is also a pointer showing where the next letter will be printed.

The type-bars are compound levers, which cause the type to withdraw radially from the inking pad, and then to move vertically upwards to the printing point, where there is a central square socket to ensure alignment when printing, independently of the guidance of the bars. The bars are double and made from steel ·02 in. thick, with the type socket between them. The return movement of the bars is ensured by a ring, which acts by its weight upon any bar not returned.

1488. Smith Premier typewriter. Lent by the Smith Premier Typewriter Co., 1908. M. 3531.

This machine, introduced in 1889, is of the type-bar class with the type-bars in a ring, striking to a point on the underside of the platen. The principal feature of the machine is the mechanism adopted for this purpose. There is a complete keyboard of 84 keys, each of which actuates a longitudinal rocker-shaft, which by an adjustable rod actuates its type-bar; each key has the same leverage and thus uniformity of touch is obtained. The type-bar rocks in steel cone bearings 1·625 in. apart on the type ring; this long bearing, which secures good alignment, is obtained with a small diameter of ring and a short type-bar, by setting the bearings tangential to the ring. Line-spacing is of three widths and is automatically done in the act of drawing back the carriage for the next line; the latter runs on balls. Where line-spacing varies, *e.g.*, in a printed form, use is made of a platen release. The platen can be swung upwards in order to see the writing without raising the carriage and can also be readily removed for the substitution of a harder one for manifolding work.

The black-purple-red ribbon is directed between two spools in a _|‾-shaped course; by a transverse movement of the slide the required colour is brought under the printing point, permitting the whole surface to be utilised, or it may be moved out of the way altogether for stencil-cutting, &c. The type are cleaned by a circular brush below the type-bars; when rotated by a crank the brush rises on its threaded spindle into contact with the type.

The machine shown, which is partly in section, is a No. 4, which writes a line 7·25 in. long.

1489. Blickensderfer typewriter. Lent by the Blickensderfer Typewriter Co., 1904. M. 3342.

This machine, patented in 1889–93 by Mr. G. C. Blickensderfer, is of the class in which the fount is on the periphery of a wheel or shuttle, but differs from the Pratt and Hammond machines in that the type-wheel itself acts as the hammer in giving the impression on the paper.

As there are two changes of case, the type-wheel has motion in three directions: axially, to bring the desired row of characters to the printing line; round its axis, to bring the desired character to the printing point; and radially towards the platen, to give the impression. The type-wheel is mounted on a pin passing through a shaft carried between cone centres, and it can be slid axially to two different positions by the "change-of-case" keys. The two other movements are made simultaneously, by a bevel pinion fixed on the type-wheel, gearing with two segments centred on the shaft, one for the right half of the bank of keys and the other for the left. When a key is depressed it causes one of the segments to rotate to a certain extent and, as the other segment remains stationary, the type-wheel rotates and at the same

time swings downwards towards the paper, till, by the further depression of the key, the wheel is accurately fixed in position by an eccentric ratchet wheel on it; the wheel then reaches the printing point, but at the moment of impression it is steadied by a comb on it engaging in a fixed stop. The type is inked by a roller which is swung out of the way by the descent of the type-wheel. There are 28 keys, controlling 84 characters, and the keyboard is so arranged that the keys most frequently used are in the lowest row.

The carriage is free, being propelled by a spring which acts as a buffer at the completion of each stroke, the recovery feeding the carriage along, after each letter is printed, by a rack motion. The machine weighs, with its case, 12·5 lbs.

1490. Remington typewriter, No. 7. Lent by the Remington Typewriter Co., 1908. M. 2986.

The original Remington typewriter was the Sholes & Glidden machine of 1867–73 (*see* No. 1474), which has been successively improved by many inventors. In the No. 2 machine (*see* No. 1476), the oscillating platen and type bars having two characters on each, so as to print lower case as well as capital letters, were introduced. The No. 4, however, printed capitals only, but it was not long retained on the market, as the demand for a machine with a change of case had been created. The No. 5 was manufactured for the British market taking paper 9·5 in. wide, and printing 84 as against 76 characters on the No. 2.

The current model, No. 7 machine, which was introduced in 1896, takes paper 9·9 in. wide, writes a line 7·5 in. long, and prints 84 characters. Numerous improvements have been introduced in this model: the platen can be released for the insertion of paper and for the adjustment of the printing point. The ribbon is wound from one spool to another by a ratchet, and simultaneously by a cam the spools are moved transversely to ensure that the whole surface shall be used; when the spool is empty a weighted lever drops out and reverses the motion. A recent attachment is the polychrome ribbon, two-thirds of whose width is one colour and one-third another. The escapement of the carriage is obtained from a narrow wheel of greater pitch than the rack, so obtaining increased delicacy of touch. There are four marginal stops, two of these can be passed over so that notes may be written in the margin or a word completed.

The machine exhibited is fitted with an improved form of the tabulator patented in 1896 by Mr. F. P. Gorin. On the front of the keyboard is an indicator with 10 plunger keys, connected with 10 levers brought together so as to occupy 10 letter spaces in a frame at the back. The plunger raises the escapement rack and simultaneously projects its lever, with which stops placed at any desired positions on a notched bar attached to the carriage come into contact. The left-hand plunger brings the carriage to rest at the right-hand end of any individual column, the next brings it one point from the right and so on up to 10 points, *i.e.*, 1,000,000 in figures or 1,000 in £ *s.* *d.*

1491. Oliver typewriter. Lent by the Oliver Typewriter Co., 1908. M. 3081.

This machine was invented and patented by Mr. Thomas Oliver in the United States in 1891–8, and is described in a British patent of 1896. The type-bars consist of 28 ∩-shaped loops arranged in two nests to the right and left of the printing point; each loop carries three characters, so that by the use of a double-shift key 84 characters can be printed by the 28 finger keys. The use of a curved bar, pivoted at its extremities, gives an exceptional virtual length of bearing, which it is claimed secures and preserves accurate alignment. The loops nest one within another, and, as the lengths of the arms vary, the shorter ones are fitted with more massive type, with the object of equalising the blows.

The paper cylinder is fitted with three rollers, the pressure of which can be eased when adjusting the paper, and there is an arrangement by which the register pawl can be lifted so as to facilitate turning the roller when drawing

vertical or horizontal lines by a pencil applied to the carriage. Either single or double spacing between lines is automatically accomplished on the return motion of the carriage by a striking motion actuated by the marginal stop; intermediate spacing is also provided for. The inking is done by a narrow ribbon, which is automatically withdrawn as each character is printed, so that visible writing is secured.

1492. Stenotyper. Received 1907. M. 3483.

This is a form of shorthand typewriter introduced in 1895 by Mr. J. F. Hardy.

The method of abbreviation used is largely phonetic and nearly all vowels except initial ones are omitted. There are six characters used, of the dot and dash form shown, and by taking them singly and in combination an alphabet of 63 letters is made up which comprises the consonants and also many of the commonest combinations of consonants in a language. There is one key lever to each character, made of sheet metal the full width of the platen; the rear edge of each is bent upward at the printing line and has the character repeated 15 times along this edge. The six keys print in double line and can all be struck simultaneously without interference. In order that both hands may be used alternately and that the corresponding fingers in both hands may strike the same keys, three of the key levers are made with duplicate keys. The highest key is for word-spacing; it marks a dash, which is also used in combination, and is struck by the most convenient finger of the hand not in use. The type strike against a platen, which is one of 15 blocks or anvils arranged in one complete helix round a cylinder. Thus only one character, or a combination of any of the six characters depending on the position of the platen, can make an impression at one time. The platen is fed forward automatically by a ratchet at each depression of a key. The paper is in the form of a continuous roll inserted on a spring core and is fed forward by two rubber-covered rollers, the lower one of which is moved by ratchets each time a key is depressed; line-spacing is therefore automatic. Inking is done by a carbon paper or ribbon the full width of the platen, wound backwards and forwards between two spools, the direction being determined by tightening and loosening thumbscrews.

POTTERY AND BRICKMAKING MACHINERY.

The moulding of articles in clay, and their conversion by firing into a material resembling stone, is one of the oldest arts and has been practised by all but the earliest pre-historic races. The first record of a potter's wheel is sculptured on an Egyptian tomb of about 4000 B.C. It consisted simply of a small round table revolving on a vertical axis, the potter giving it an impulse occasionally by hand to maintain the motion; this arrangement is still to be seen in India. A later monument shows the addition of a larger wheel below by which the speed is maintained by the feet, a construction that continues in use to the present day. The potter's wheel driven by pulley and band (*see* No. 1493) was introduced more than 100 years ago and was the first step towards the power-driven wheel. The great difficulty then experienced was due to the continually varying speed required by the potter, this changing with the different positions of the work that he was handling. By a simple

arrangement the speed of a power-driven wheel is now made to vary with the degree of pressure that the potter exerts upon a foot lever and is therefore directly under his control (*see* No. 1494).

Brick and tile-making have been practised by all the civilised nations of antiquity. Bricks were made by hand from worked clay to which a binding material such as straw was added, and were either sun-baked or kiln-fired; the manufacture has undergone but little change to the present day. The working, or tempering, of the clay was formerly done by treading or by turning with the spade, but is now usually done in a rotary machine called a pug-mill (*see* No. 1495). In making bricks by hand, a lump of tempered clay is thrown into a wetted wooden mould, without top or bottom, but that fits on a board which has a projection or "frog" to leave a recess in the brick. The clay is pressed by hand well into the corners of the mould and the excess then scraped off by a "strike."

Machines for brickmaking are of two classes: those constructed to work the clay in a wet or plastic state, and those to work in the semi-dry condition. Plastic machines are simple and do not require heavy plant (*see* No. 1495); but, the semi-dry process makes a brick which does not require the preliminary drying for from three to six weeks before burning. In the dry-clay machine, the vertical shaft of the pug-mill has knives like screw-blades which force the clay down into a pair of moulds in a horizontal table below, that turns intermittently. The table rotates, and the clay in these moulds is powerfully pressed by descending plungers, either in its original moulds or in others.

Tiles and pipes are manufactured similarly to plastic bricks, with the orifices modified to suit the section desired (*see* No. 1498), but plastic bricks and tiles are sometimes pressed before drying in special machines (*see* No. 1499).

1493. Model of potter's wheel (working). (Scale 1 : 2.) Lent by William Boulton, Esq., 1891. Plate VIII., No. 6. M. 2378.

This model shows a throwing-wheel such as has been in use for the past 100 years in forming various articles of pottery. The attendant, generally a woman, turns the large wheel by means of the winch handle and thus rapidly rotates the vertical spindle carrying the wood block or head on which the potter shapes his clay. The speed of revolution is varied by the attendant in conformity with the verbal instructions of the "thrower" (potter) to suit his particular requirements.

1494. Model of power-driven potter's wheel. (Scale 1 : 2.) Lent by William Boulton, Esq., 1891. M. 2379.

This machine, patented by Mr. W. Boulton in 1867, is constructed for driving by steam power, a variable-speed friction gear enabling the revolutions of the head to be varied immediately to suit the requirements of the potter, although the machine is being driven from shafting running at a constant speed. The vertical spindle carrying the head is provided with a

cast-iron cone, having a curved outline, against which is pressed another cone, inverted and covered with softer material, so that the two surfaces can only touch over a small distance. This second cone is driven by a belt or rope at a uniform speed, but by means of a foot lever the potter can slightly sway it so as to alter the contact point of the cones and therefore their relative speeds.

1495. Model of brickmaking machine. (Scale 1 : 4.) Contributed by Messrs. H. Clayton & Co., 1860. M. 510.

This machine was patented by Mr. H. Clayton in 1852. It consists of a vertical pug-mill containing a number of revolving inclined blades, by which the clay is worked and at the same time forced downwards. In the lower portion of the mill is a piston, which is reciprocated horizontally from a crank-shaft below. At opposite sides of the mill are orifices, through which by the reciprocation of the piston the clay is forced outwards at either side alternately as a continuous bar of rectangular section 9·5 in. by 4·7 in. The bar is received on a table formed of rollers, and when a sufficient length has been delivered and during the interval of rest of the bar, a swing frame of stretched wires is pulled over by hand, and in its passage the wires cut the bar into a like number of bricks.

The sides of the dies are formed by rollers which are driven intermittently, during the period that the clay is being delivered, by a clutch gear controlled by a cam on the crank-shaft. In this way the friction of the die is considerably reduced: with the same object the dies are lubricated by water supplied from a cistern above.

1496. Models of stiff plastic brick moulding and pressing machines. (Scale 1 : 4.) Lent by Messrs. Wm. Johnson & Sons, 1899 and 1904. M. 3062 and 3369.

This is a combination of two power-driven machines patented in 1884 by Mr. W. Johnson: one is for moulding bricks and the other for compressing and consolidating them.

In the moulding machine, the clay from a grinding mill and mixer is fed into a hopper which surmounts a chamber containing a horizontal plunger driven by a rod from a crank-shaft. The plunger, which is provided with an orifice for the return of any clay in excess, pushes the material into one of four recesses or moulds in a horizontal drum; this drum is intermittently rotated by a crank and ratchet rod, and held stationary during the intervals by a catch moved by another crank. The bottoms of opposite moulds are connected together, and form loose pistons which push the brick out of one mould on to a table while the diametrically opposite mould is being filled up. An inspection door is provided on the front of the hopper.

The moulded brick is taken by a boy and placed on the table of the pressing machine, which has a vertical plunger, sliding in guides and operated from a crank-shaft through a double-ended rocking lever and connecting rods. The bottom of the brick mould is moved vertically by a lever and a cam on the crank-shaft, the motion being so timed that the pressed brick is at the top of the mould and at the table level, when the compression is completed. The finished brick is then displaced by a fresh one pushed into position by an arm worked by another cam. The bricks are sufficiently dry to be taken direct to the kiln. The crank-shafts of both machines are driven at a reduced speed, by spur gearing, from countershafts provided with flywheels and pulleys.

1497. Model of brickmaking machine. (Scale 1 : 8.) Lent by Sir James Farmer & Sons, 1902. M. 3225.

In this machine, patented by Sir James Farmer in 1885, plastic clay is delivered under pressure, by rollers, into a pug-mill which then forces it into the periphery of a revolving cylinder, where it is pressed by dies before

being delivered on to a travelling band which conveys the finished bricks towards the kilns.

The clay is fed into a hopper at the top of the machine, and passes downwards through a pair of horizontal rollers which fit closely over the top of a horizontal pug-mill, the revolving inclined blades of which assist the clay in its passage towards the delivery end. Outside this end of the mill, and fitting it closely, is a revolving horizontal cylinder having its surface penetrated by rectangular holes forming moulds, each of which is provided with a plunger, forming the closed end of the mould and having rollers fitting in grooves on a stationary cam within the cylinder. After a mould has been filled by the pug-mill, the revolution of the cylinder carries it upwards, and when in its highest position a block moved by a crank-shaft above the cylinder is pressed into the mould, thus forming the frog on the brick and generally consolidating the material; these pressing blocks receive a combined motion which gives them a radial course while entering and leaving the mould. As the cylinder further revolves the plungers forming the bottoms of the pressing moulds are, by the internal cam, forced to the circumference of the cylinder so as to expel the pressed bricks, any tendency to adhere being overcome by a stationary blade close to the cylinder.

The rolls, pug-mill, cylinder, and pressers are all driven by spur and bevel gearing from an upper shaft, which is worked by spur gearing from a belt-driven countershaft; the moulds are sometimes steam-jacketed, the steam entering through the centre of the fixed spindle.

Some specimen bricks as prepared in this model machine are shown on the travelling band.

1498. Model of drain-pipe making machine. (Scale 1:4.) Contributed by the Commissioners for the Exhibition of 1851. M. 101.

This is a model of a portable hand-machine for making drain-pipes, patented by Mr. J. Hart in 1851. It consists of a long box, in which two pistons are made to reciprocate by means of a rack and pinion. Pugged clay is introduced into each end of the box alternately as the piston recedes, and is forced out through dies at each end as the piston advances towards them. Rollers are provided to receive the pipes as they emerge from the dies. The dies can be changed according to the section of pipe required.

1499. Press for making tiles. Contributed by J. A. Wade, Esq., 1874. M. 1329.

This is a portable hand-machine for making roofing tiles, and was patented by Messrs. Wade & Cherry in 1873. The tile is formed by pressing a lump of plastic clay within a suitable mould; where transparent tiles are required, molten glass is similarly treated, but in that case the mould must be kept hot.

The mould is formed on the top plate, and has a hinged cover with a counterbalance; the front of the cover is loose and can be pushed out by a handle so as to detach the finished tile. The bottom of the mould is formed on a separate plate which is given an upward lift of ·6 in. by means of a long lever; the lump of clay contained in the closed mould is thus caused to completely fill it, and at the same time is somewhat consolidated. The compressing, unlatching, and opening are all effected by one stroke of the lever.

AGRICULTURAL MACHINERY.

Although agriculture is the oldest and most important industry, but little attention was paid in the past to the improvement of the implements used, and it is only since about 1850 that the large field that agriculture offers for mechanical appliances has received serious attention. A few

primitive tools evolved by ages of experience had been brought into a form suited to certain localities, but of general machinery the farmer was quite independent. For the few purposes to which power could be applied, the farm animals were used, and to some extent wind and water power; but, after the invention of the high-pressure engine, steam power was soon adopted on many farms. In 1803 a stationary engine in East Lothian was employed in thrashing, and many such engines were subsequently erected for that sole purpose. Ploughing by steam power was tried as early as 1832, but it was not till 1855 that it was rendered a success.

Tilling and Sowing.—Ploughs were the only agricultural instruments used by the ancients, and were a development of hand tools now surviving, as the hoe, pick, and hatchet. Among primitive tribes the plough still remains in its earliest form, consisting of a forked bough from a tree, with one branch cut very short and pointed. When pulled by oxen a heavier branch could be used, so giving a larger rut or furrow that more quickly completed the work. The Romans added the coulter, or front cutting knife, and the mouldboard, which enables a furrow slice to be turned over. The improvements that have since been made are in the correct formation of the parts and the exclusive use of iron in the construction. The chilled cast-iron share, which, while it slowly wears away, is continually sharpening its cutting edge, was invented by Robert Ransome in 1803, and is the greatest single improvement made in modern times.

Ploughing by steam power is now confined to two distinct methods, although several others have been tried; in both of these a traction engine is employed, and its power is transmitted by a wire rope working on a drum. In Fowler's system an engine on each side of the field is required, and these draw backwards and forwards a balance plough, making from two to eight furrows at each passage. In Howard's system only one engine is used, but two travelling anchors or pulleys are required.

Cultivators are chiefly used to break up unreclaimed land, or such as would offer too solid a resistance if attacked at once with a plough. The cultivator, having simple vertical knives or coulters, cuts open the soil, without attempting any horizontal cutting or turning over, but greatly facilitates the subsequent ploughing.

Harrows are used to pulverise land that has been ploughed, to remove weeds, &c., and to cover seed. The early forms were wooden frames with spikes projecting downwards, but now such implements are made entirely of iron. Harrows with revolving tines are used, and also those consisting of a net of iron rings known as chain harrows.

Rollers and clod-crushers are used for compressing and smoothing the surface of land or for breaking up clods. Rollers

were formerly cut from the bole of a tree, but cast iron is now generally employed. They are usually made in sections, to facilitate turning, and the surface may be plain or fluted (*see* Nos. 1506–8.).

Drills have quite superseded hand labour in sowing seed, owing to the uniformity of their distribution and depth of sowing, and the facility and economy with which at the same time they will distribute manure; broadcast seed-sowers of simple construction are, however, in use for certain work.

Hoes are the oldest agricultural tools, and were probably used for breaking up the soil long before the invention of the spade. They are used to lift the soil between growing seed crops, and to destroy weeds, &c. As an implement, a large number of hoes are attached to a frame carried on wheels and fitted for horse traction (*see* Nos. 1512–14).

Harvesting.—Reaping and mowing machines have generally replaced the sickle and scythe for cutting corn and grass, except in a few confined or hilly places. Reaping machines driven by oxen are said to have been in use in Gaul about A.D. 23; the animal pushed the machine before him as in Bell's reaper (*see* No. 1515), and the ears of corn were pulled off by a long horizontal comb as in the modern Australian stripper. Little advance was made until early in the 19th century, when several inventors turned their attention to the subject of producing a machine that would cut off the corn stalks at least as close to the ground as the hand reaper. One of the most successful of these inventors was James Smith, of Deanston, who used a horizontal revolving disc as a cutter, but the first efficient machine on the present shearing principle was that completed in 1826 by the Rev. Patrick Bell (*see* Nos. 1515–6). This was followed in 1833 by McCormick & Hussey's machine in America, which strongly resembled the arrangement now universally adopted, but it was not till after the Great Exhibition of 1851 that reaping machines came into general use. There are now three classes of machines:—Back delivery reapers, which simply cut the corn and leave it in a swath to be collected and bound into a sheaf by hand; by a slight alteration of the speed of reciprocation of the knife this is used for grass, and is called a mowing machine. Side delivery reapers, where the corn falls on a platform and is raked off at the side by revolving rakes, the sheaf being bound by hand. Self-binding reapers, which deliver the crop ready-bound into sheaves (*see* No. 1520); this type is rapidly superseding all others.

Haymakers are used to scatter the mown grass more evenly and rapidly than can be done by hand; usually they operate by revolving forks, but recently a motion resembling that of a hand fork has been introduced (*see* No. 1521). To collect the hay into "windrows" previous to "leading," horse-rakes are used; they consist of a series of teeth shaped like sickles, which can all be raised by a lever when a row is to be left.

Thrashing machines, for separating the grain from the straw or chaff, now do the work that for ages had been very imperfectly done by the flail, by treading out by animals, or by their drawing a sleigh over the thrashing floor. In 1787 Andrew Meikle produced a thrashing mill which embodied most of the essentials of the present thrashing machine, but in a very imperfect form. The latest machines perform all the operations of separating the grain from the straw, chaff, broken ears, dirt, and stray seeds, and then grade it into different qualities. Where barley is being thrashed an "awner" is used, which breaks off the awns or beards after the straw has been removed. Some thrashers do not finish, however (*see* No. 1526), this being done in a separate machine known as a corn-dresser.

1500. Models of Siamese ploughs. (Scale 1 : 8.) Lent by L. H. Pritchard, Esq., 1908. M. 3549.

These represent the primitive form of plough used in the rice fields of Siam. They are made entirely of wood and consist of a long curved pole to which a yoke is attached, and a cross piece mortised in at the rear end, the lower end of which carries the ploughshare while the upper end serves as a guiding handle. The share is formed with an upward projection having a curved face which slightly turns the shallow furrow made. The ploughs are drawn by a pair of water-buffaloes, the yoke bar resting on their necks and being secured by a cord passed underneath.

1501. Model of double-furrow plough. (Scale 1 : 5.) Received 1906. Plate IX., No. 1. M. 3449.

The double plough, although invented much earlier, was not extensively used until the beginning of the 19th century. By the use of such ploughs one man is able to perform twice the amount of work that he could with a single plough, in many cases requiring only one extra horse.

In ploughing, the soil is first cut vertically by a knife called a coulter, and then cut horizontally by the ploughshare, the slice of earth so detached being turned over by a curved plate known as a mould-board.

The model represents a double-furrow plough made by Mr. J. P. Fison about 1872. The plough has two parallel iron beams stayed together and each carrying a share, mould-board, and coulters. One of the beams is adjustable sideways so as to vary the pitch of the furrows from 7·5 in. to 10·5 in., or it may be entirely removed. The main beam has long handles at its rear end, by means of which the plough is guided and turned, while its front end carries an adjustable head having an eye through which passes a draw bar attached to the beams between the two plough frames. The shares and mould-boards are fitted to wrought-iron frames bolted to the beams, and the coulters have round shanks held in sockets and clamped to the beams by eyebolts, their angles being adjusted by set screws bearing on the beams. Skim coulters, whose function is to pare the surface of the land and turn in vegetation to ensure its complete burial, are fitted in front of the main coulters. The front end of the plough is carried by a pair of wheels, one of which runs in the furrow and the other on the land. These are adjustable vertically and regulate the depth of the furrow. A smaller wheel at the rear end, running in the furrow, carries the weight and reduces the draught. The land side of the rear frame is fitted with a plate which bears against the vertical side of the furrow and takes the thrust of the mould-board. The dimensions of the standard slice are 9 in. wide by 6 in. deep, and it is turned through an angle of 135 deg.

1502. Model of two-furrow plough. (Scale 1 : 4.) Lent by Messrs. J. C. & T. Yates, 1894. M. 2690.

This represents a modern double-furrow plough; similar ploughs are arranged to turn three furrows at a time, and where oxen are used for pulling, such larger ploughs are extensively employed. The model shows a plough with a timber beam strengthened with wrought iron, and provided with a notched bar in front so that the draught may be exerted exactly in line with the combined resistances of the two shares, and the slice be maintained of constant width. By carrying the body of the after plough by slotted or adjustable brackets the width of the furrows can be varied from 7 in. to 10 in. To lift the plough, a hand lever is employed which moves two arms, one carrying a wheel and the other a shoe, the wheel and shoe being simultaneously depressed by pulling the lever. By these means the plough is lifted out of the ground and its weight carried on the two wheels and the shoe. The front wheel is adjustable and determines the depth of the cut.

1503. Model of Martin's cultivator. (Scale 1 : 4.) Presented by Martin's Cultivator Co., 1905. M. 3390.

This form of cultivator, which was patented by Mr. W. C. Martin in 1898, is used for breaking up and pulverising the soil, preparing seed beds, and other similar operations. The size represented has seven tines and works a width of 5·25 ft. to a depth of from 1 to 8 in.

The implement consists of a frame, at the back of which is supported a transverse shaft having at its ends crank arms with pins carrying the wheels. At intervals along this shaft are placed blocks clamped to a flat bar behind them. The tines are formed of rigid curved bars, to the lower ends of which are bolted reversible shares arranged in two rows, whose points cut the soil tangentially. The front end of each tine passes freely through slots in the lower part of one of the blocks and is attached by a pin to one end of a bent spring whose other end is clamped to the block and cross bar. By this arrangement the tine has a vibratory motion which is limited by the slots so that it cannot pull back too far or rise out of the ground. To the wheel shaft is attached a lever working round a quadrant fixed to the tine bar, and by means of this the wheel cranks may be set at any angle, so regulating the depth of cut and keeping all the shares at the same level. When turning, the tines are lifted clear of the ground by another lever which tilts up the tine bar. The forward end of the frame is carried by a small wheel with a swivel mounting and an arrangement for adjusting the height. A seat is provided for the attendant.

1504. Models of Siamese harrows. (Scale 1 : 8.) Lent by L. H. Pritchard, Esq., 1908. M. 3550.

These represent the form of harrow used in Siam and other parts of the East. They are simply large wooden rakes provided with a guiding handle and drawn by oxen yoked to the pole.

1505. Model of rotary harrow. (Scale 1 : 8.) Lent by Messrs. Stanford & Co., 1898. M. 3013.

This form of harrow, patented by the makers in 1884, is chiefly used for passing over land that has been ploughed, so as to break the clods and prepare a seed bed; it works to a depth of from 3 to 8 ins. The size represented, which covers a width of 7·5 ft., is drawn by three horses.

The machine consists of a wrought-iron frame carrying brackets, in which are supported two horizontal drums provided with projecting prongs or tines. These tines are so curved that they readily penetrate the earth, while on leaving it they tear it up in a manner resembling the action of a hand fork. The tines on the two rollers hit and miss, and the distance between the rollers is regulated by adjustable front bearings. When at the end of the

land, the implement is lifted clear of the surface by the attendant releasing a lever, which allows two carrying wheels to swing into action. The forward weight of the frame is carried by a pair of small leading wheels, with a swivel mounting and an arrangement for adjusting the height.

1506. Model of clod-crusher. (Scale 1 : 6.) Contributed by the Commissioners of Patents, 1857. M. 105.

This model represents the clod-crusher patented by Mr. Crosskill in 1841. It consists of a number of cast-iron discs threaded loosely on a horizontal axle-tree. The edge of each disc has projecting V-shaped teeth, and also lozenge-shaped teeth on the sides nearly radial in direction. Two smooth wheels of large diameter are placed on the extremities of the axle when the implement has to travel for some distance over roads.

1507. Model of clod-crusher. (Scale 1 : 6.) Contributed by Messrs. Newton & Sons, 1862. M. 719.

This is a model of Mr. W. C. Cambridge's clod-crusher, patented in 1844. It has a number of cast-iron discs placed side by side on a horizontal axis, but they are alternately toothed and plain on the edges. The toothed discs are greater in diameter than the others, but, having a larger hole in the centre, all bear equally on the soil; the sliding movement so resulting prevents clogging in moist ground.

1508. Model of clod-crusher. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2685.

This model was shown at the 1851 Exhibition, but the arrangement was invented prior to 1845. It is a form of clod-crusher in which, for moving the machine over hard roads, two travelling wheels carried on independent overhanging axle-trees are introduced. By means of screws and suitable guides the axles can be quickly elevated or depressed, so that when on the fields the travelling wheels can be lifted well above the earth.

1509. Model of corn drill. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2681.

This is a model shown at the 1851 Exhibition, and represents a machine for drilling corn into the earth in parallel rows, and delivering a uniform amount per yard irrespective of the speed at which the machine moves. Details of this machine were patented in 1842 and 1846, but the general arrangement is substantially that still followed.

The body of the machine is carried on two large driving wheels, and an independent fore-carriage is employed by means of which the attendant may accurately steer the machine and thus avoid irregularity in the sowing—a matter of considerable importance if a horse-hoe or other implement is afterwards to be employed between the rows. The seed is carried in a hopper at the top of the casing, from which it passes through five adjustable doors into the trough. Above this trough is a horizontal shaft, driven by spur gearing from one of the travelling wheels, and having on it five discs each provided with metal cups, which, as the discs revolve, dip down into the seed and lift it up, in the same manner as the old Persian bucket-wheels raised water. On both sides of each disc is a spout into which the elevated seed drops, and by a series of nested funnels is led down to a groove formed in the soil by the drill coulter—the model having ten of these. Each drill is carried on a lever so that it will rise independently and not be damaged should it meet with any solid obstruction, while a windlass at the back of the machine raises all the drills simultaneously from the ground, so that the depth of the sowing can be readily altered. The quantity sown is varied by the use of change-wheels, while to correct the level of the machine when on

sloping ground a screw adjustment is provided. When travelling only, the feed mechanism can be thrown out of gear by a lever which lifts the overhanging toothed wheel.

1510. Model of general seed drill. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2687.

This model was shown at the 1851 Exhibition, but the arrangement was patented in 1844. It is a seed drill for general purposes, arranged to drill in seed and any suitable manure at the same time. The manure and the seed are contained in two separate chambers at the top of the machine. The seed is dealt with in the same way as with an ordinary corn drill, but beneath the seed mechanism is arranged a shaft with a number of arms terminating in cups, by which the powdered manure is thrown into conical hoppers that deliver it into the conductors conveying the seed to the coulters. Various arrangements of the coulters can be made so as to give several different distributions of the seed and manure. The seed mechanism is worked from one of the driving wheels, and the manure distribution from the other, but either can be thrown out of gear by the hand-levers provided.

1511. Model of turnip drill. (Scale 1 : 4.) Lent by Messrs. J. C. & T. Yates, 1894. M. 2691.

This is a model of a machine for sowing the seeds of turnips and similar roots. The seeds are drilled on ridges and the machine is arranged for drilling two ridges at once. It has two light travelling wheels, from one of which the mechanism for the ordinary seed-lifting cups is driven; this gear and the seed are confined in a central box. From the box the lifted seed is conducted to the two coulters, which by attached levers are readily under the control of the attendant. In advance of each coulter runs a wide concave metal roller, which by its pressure prepares the ridges into which the seed is drilled. Behind the coulters follows a wooden roller which, pressing on the ridges, consolidates the earth over the seed.

1512. Model of lever horse-hoe. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2680.

This model was shown at the 1851 Exhibition, and embodies inventions patented in 1842 and 1849. It is a machine for scarifying the spaces between the rows of young plants, the seed for which has been drilled in, and contains 14 hoes, each carried on a separate lever so arranged that the hoes will pass undamaged over any large stones; two hoes pass through the space between each row. To prevent damaging the crop, each hoe and its lever are adjustable so that they may be accurately pitched to suit the sowing, and the two travelling wheels for the same reason are carried on separate axle-trees so that the gauge can be adjusted. The hoes are also irregularly arranged so as to minimise the chance of tearing up the crop, and, by a lever that rotates two eccentrics carried on a shaft, the whole of the hoes can be instantly elevated clear of the ground when desired. To correct any irregularity in the movement of the horse pulling the machine, the hoe-frame is carried on swinging links, and by a shaft brought to the back of the machine the attendant can move the set sideways in either direction, so as to keep the holes accurately between the rows of young plants.

1513. Model of link-lever horse-hoe. (Scale 1 : 8.) Lent by Messrs. Barnard & Lake, 1891. M. 2396.

This is a machine, patented by Mr. F. C. Lake in 1887, for hoeing the spaces between the rows of a crop that has been sown by a drill. It consists of a frame carried on two wheels, to which is attached behind a sliding frame carrying ten hoes. The sliding frame is maintained accurately in its true position relatively to the crop by means of a steering rod, attached to the main frame and passing through an eye on the hoe frame. The depth of

the hoes is regulated by a worm gear that, by means of two levers and chains, lifts the whole of the sliding frame, and a lever stopping into a quadrant gives an adjustment for their inclination. The hoes can be lifted clear of the ground by the wooden handle at the back, and a catch is provided that will retain them in this position.

1514. Model of expanding horse-hoe. (Scale 1 : 8.) Lent by Messrs. Barnard & Lake, 1891. M. 2395.

In this implement, patented by Mr. F. C. Lake in 1877, there are five shares so mounted that the total width of ground acted upon can be readily altered. The front share is fixed to the frame while the four others are secured to two arms pivoted near the front and capable of being opened outwards by means of a pinion gearing with two curved racks attached to the stems of the hindermost shares. The stems are mounted in sleeves and, by means of the curved arms at the top, keep the shares pointing straight whatever be the extent to which the machine is opened. When set to the desired width the parts are clamped rigidly together by tightening a few nuts.

1515. Bell's reaping machine. Made by the Rev. Patrick Bell, LL.D. Received 1868. Plate IX., No. 2. M. 1103.

This is the original reaping machine invented in 1826 by Dr. Bell, but before it was removed to South Kensington in 1868 the cutting mechanism had been altered to the later form now on the machine. The original construction is shown in an adjacent model, in which the cutting is performed by a series of double-edged shears, with the moving blade in each pair actuated by a common rod driven by a crank worked from the travelling wheels. Portions of these shears are shown on the pedestal of the reaper. The machine was a success and is recorded to have cut on an average 12 acres per day. It is stated that many of these reapers were made and that some were sent to America, from which country the much improved arrangement now in use was brought over many years later.

The machine has an open timber framework, carried on two large driving wheels with wide tires, and two small wheels in front that directly support the cutting blades and so secure uniform clearance. It was propelled by two horses walking behind it and exerting their effort upon a pole that pushed the machine before them; steering was done by the driver, who held a bar connected with the horse-pole.

In front is a revolving frame or collector, which supported the corn, and when cut forced it backwards on to the inclined travelling apron by which the corn was delivered at the side of the machine. The apron driving gear is reversible so that the machine could work either-handed.

1516. Model of original reaping machine. (Scale 1 : 48.) Presented by the Rev. Patrick Bell, LL.D., 1868. M. 1092.

This is a model of the original reaping machine, made in 1826 by the Rev. Patrick Bell, whose photograph accompanies it. The construction can be more clearly seen in the machine itself (*see* No. 1515), but in this model the original arrangement of shears is preserved, while that on the actual machine is of much later date and was fitted by the inventor's brother.

1517. Model of McCormick's original reaper. (Scale 1 : 6.) Presented by the McCormick Harvesting Machine Co., 1901. M. 3142.

The machine represented appears to have been constructed and worked in 1831 in Virginia, U.S.A., by Cyprus H. McCormick, who, in 1834, patented, amongst other details of the reaper, the use of a vibrating blade,

operated by a crank and having either a smooth or a toothed edge, working between fixed wires, above and below, to support the straw while being cut. His invention had, however, been anticipated, so that his first patent was invalidated, but he greatly developed the machine and manufactured it on an extensive scale, so that to his labours is largely due the practical introduction of this important appliance.

The machine consisted of a timber frame, drawn by a horse on which the driver rode; it was supported on two wheels, the larger of which carried most of the weight and, by bevel gearing, drove a crank that reciprocated a horizontal blade provided with cutting teeth; the blade worked in slots through a number of spearheads, or fingers, attached to the front of a low platform, so that the fingers supported the stalks of corn while the reciprocating blade cut them through. To prevent the stalks from being pushed forward as the machine advanced, a revolving four-armed frame, or reel, driven by leather belting, was provided, by which the standing corn was supported and that which was cut was compelled to fall back upon the platform, from which it was raked in quantities suitable for forming separate sheaves by an attendant walking at the side. A protecting loop was added to deflect the standing corn from the side of the horse, and on the other side of the machine was a divider which separated the corn to be cut from that beyond; a canvas dividing screen was also provided to prevent the cut corn from falling off the wrong side of the platform.

1518. Model of McCormick's reaper of 1847. (Scale 1 : 6.) Presented by the McCormick Harvesting Machine Co., 1901. M. 3143.

This shows McCormick's machine as improved by his patents of 1845–47; the width of the cut had also been increased from 4 to 6 ft., and provision made for the use of two horses in haulage. The cutting blade was supported at the back and below almost to the edge, and the spearheads or fingers did not reach below it. By tho use of an additional lever the driving gearing was brought forward so as to leave room for a seat for the attendant, who cleared the platform, while the driver rode on one of the horses. The dividing arrangements on each side were also further developed, and means were added for altering the height of the reel to suit the length of stalk being cut.

1519. Model of McCormick's reaper of 1851. (Scale 1 : 6.) Presented by the McCormick Harvesting Machine Co., 1901. Plate IX., No. 3. M. 3144.

This represents the machine shown at the 1851 Exhibition, where it was one of two which created great interest and led to the general introduction and use of reaping machines in this country.

It differed from the earlier examples in that both the driver and raker were seated on the machine, and also in having the reel driven by pitch chain. The alterations necessary for suiting corn of different heights were provided for by so constructing the reel that its diameter could be quickly changed. Provision was also made for altering the height of the cutting edge from the ground, both the main wheel and the outer wheel being carried on adjustable swinging arms and suitable modifications made in the gearing.

1520. Sheaf-binding harvester. Lent by Messrs. R. Hornsby & Sons, 1890. M. 2315.

This is a modern reaping machine with mechanism added by which the corn as cut is made up into sheaves and tied by string before being discharged. The corn, as fast as it is cut, is lifted from the level of the canvas platform on which it falls, between two continuously travelling canvas elevators. On reaching the top of the elevators, it is passed by a conveyor roll above the main travelling wheel to the binding table. Here two curved

arms, continuously working, pack the stalks together until there is sufficient to form a sheaf, when the downward pressure of the corn, increased by the thrust of the packers, depresses a board which throws the binding mechanism into gear, so that the sheaves made are of a constant size, while the number varies with the thickness of the crop. A long curved needle carries the string from a large ball, right round the sheaf, the knotting mechanism then, seizing both ends of the string and twisting it into a loop, forms a tight crochet knot; the string is subsequently cut off and the end retained ready for forming the next knot. The finished sheaf is dropped or lowered from the table to the ground by the side of the machine.

1521. Model of hay tedder. (Scale 1 : 8.) Lent by the Massey-Harris Co., 1893. M. 2499.

This model shows a modern form of machine for tossing hay. The hay is thrown over by six forks, which, instead of the rotating motion adopted in other types of haymaking machines, have a kicking motion closely resembling that of a hay-fork used by hand.

The machine has a timber frame terminating in shafts so that it can be drawn by a horse, the forks working behind. Two large carrying wheels, running loose on their axles, support the machine, and each carries a spur wheel, which by an intermediate wheel drives a three-throw crank to the pins of which the middle of each fork handle is attached. The upper end of the handle is held by a link connecting it with the framing, each of the driving wheels working three of the forks. A seat is provided for the driver from which he can control the distance of the forks from the ground and can also throw the tedding motion in and out of gear.

1522. Model of swath turner. (Scale 1:4). Made by Martin's Cultivator Co., 1907. M. 3511.

This represents a machine used for turning over the swaths of hay while it is being cured. It was patented by Mr. W. E. Martin in 1903.

The machine is carried on two wheels which drive two revolving rakes set obliquely to the direction of motion and having spring tines which always remain vertical; the mechanism employed is an application of Boehm's method of coupling two parallel shafts by means of a number of inclined links or coupling rods. The wheels run loose upon a transverse axle fixed to the framing and from this axle two bars project straight forward; they are then bent horizontally through 60 deg,, and then forward for a short length, where their ends are supported in bearings whose height is adjustable. On each of these bars, close up to the ends of the oblique portion, two hubs are mounted having four arms, the corresponding ends of which are coupled by four oblique rods, whose parallel ends bear in holes in them. The tines are fastened to these rods and always hang downward. The rear hubs are driven from the carrying wheels by a sleeve and bevel gearing, through clutches operated independently by hand-levers. The heights of the turners are adjusted by hand-levers, while foot-levers are also provided for suddenly raising them when passing an obstruction. Stripping bars are fitted to prevent the hay from being carried round; solid discs are fitted behind the turners and a baffle plate between them. A seat is provided for the driver.

1523. Model of hay elevator. (Scale 1 : 8.) Lent by Messrs. G. H. Innes & Co., 1904. Plate IX., No. 5. M. 3339.

This appliance for lifting hay, straw, &c., and depositing it in a high heap so as to form a rick is a development of a machine first introduced about 1850. It consists of a wagon on which is mounted a long inclined trough in which work two endless pitch chains connected by transverse bars fitted with prongs or forks which carry the material from an adjustable hopper at the bottom of the trough and deliver it over the centre of the site

of the stack; the chains are driven by sprocket wheels from a horse gear or by belting from a portable engine. The upper end of the trough is supported by means of a bar which slides under while it is being elevated by two hinged props, combined with annular wheels worked by pinions and winch handles. The hopper end of the trough is mounted on a hinged frame which can be gradually raised and at the same time moved outwards by means of a rope and winch handle. As the stack increases in height this enables the delivery to be always near the centre and the stack can be topped up without any pitch hole. The whole machine can be folded up into a small space for travelling. In a modification of the machine, the hopper can be lowered until the forks touch the ground when the hay, &c., can be pitched directly from a sweep rake on to the stack.

1524. Model of a rick borer. (Scale 1 : 5.) Lent by Messrs. Workman & Sons, 1894. M. 2677.

This is a model of an instrument used for cutting a circular hole downwards into a heated haystack, in order to allow the external air to reduce the temperature by ventilation. It consists of a shell cutter with a long square shank, that can be further lengthened by extension rods. A cross handle that can be slid along the rods is provided for rotating the cutter by hand.

1525. Model of ensilage stack press. (Scale 1 : 12.) Lent by the Aylesbury Dairy Co., 1890. M. 2324.

When it is impracticable to dry hay in the open the crops may be stored wet, without being liable to spontaneous combustion, if sufficiently compressed. This may be done in a silo, or in a stack press as shown in the model, which represents a 15-ton stack press on the Johnson system. The rick is built over timber logs laid in the ground and projecting beyond its sides. Before thatching, galvanised wire ropes are carried over the top of the stack and down to small winches secured to the timbers. These winches, by means of a long lever, enable a heavy pull to be exerted upon the ropes and also form a ready means for continuing the pressure as the ensilage becomes more compact.

1526. Model of portable horse-power thrashing machine. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2679.

This model was shown at the 1851 Exhibition and embodies inventions patented in 1843, 1844, and 1850. The drum has five straight iron blades as beaters, and the "concave" is of ribbed iron plates separated by spaces covered with wire screens. The corn is thrashed out of the straw by the rapidly revolving beaters, which knock out the grain as the straw is being carried round in the small space between the drum and the concave, the empty straw finally being ejected at the lower end of the drum. Here the straw passes over a wooden grid which recovers any short ears that may have been carried round unthrashed. The grain thrashed out drops through the concave into the space at the bottom of the machine, and is removed at intervals through the side doors provided. The concave is hinged and the clearance is readily adjustable by screws.

The corn from these machines was afterwards finished in a corn-dresser, but self-acting straw-shakers that removed any grain remaining in the straw were frequently fitted to such thrashers. The machine was driven by animal power, steam, or other means; the horse gear represented is arranged for four horses, which, working at the rate of 2 miles per hour or 3 rounds per min., are stated to have thrashed as much as 60 bushels per

hour. To render the machine portable, the horse gear is fitted with an axle having two road wheels; the thrashing machine can be placed upon the horse gear, so that the whole apparatus travels on two wheels.

1527. Model of thrashing machine. (Scale 1 : 4.) Made by W. Hailstone, Esq. Received 1900. M. 3137.

This represents the form of double-blast machine made in 1860 by Messrs. Wallis, Haslam & Steevens, but the general arrangement is that still found in all machines for thrashing the grain from the stalks of corn and separating it from the chaff and similar materials; the model has, however, been considerably sectioned so as to show the internal construction, while the platform and other boards have been placed in the position for working and not as they are when the machine is closed for travelling.

When thrashing is in progress, the sheaves of corn are opened and placed on the platform, while an attendant, standing in the closed recess, or dickey, in front of the hopper, or mouth, throws the corn, at an angle of about 45 deg., into the space at the bottom of the hopper; here it is caught by the ribbed beaters of a drum making about 1,000 revs. per min., which carry it round through the space between them and a curved grid, or concave, which delays its passage to such an extent that the grain is knocked out of the ears of corn and passes through the grid, while the long straw is carried round and delivered at the opposite edge. The grain, chaff, and short straw, after passing through the bars of the concave, slip down an inclined board and are delivered at the higher end of a sloping sieve, or caving riddle, which is rapidly reciprocated longitudinally, so that the corn and chaff fall through the holes in the riddle, while the larger pieces of broken straw pass along and are delivered at the end, where they fall on to the caving board for removal. The corn falls on to a lower vibrating frame carrying a board on which it travels till it drops over the edge on to a finer screen reciprocating with it; through the meshes of this chaff riddle a blast of air, from a revolving fan, is continually rising, so that any kind of grain, owing to its density, passes through the sieve, while chaff and other light particles are blown away.

The grain now moves nearly horizontally to the side of the machine, where by a cup elevator it is raised to the level of the top; it is then allowed to fall in front of the blast from another fan, by which any remaining light particles are removed and the grain separated, by a dividing board, into two grades which pass into separate sacks attached to external hooks.

The long straw thrown out by the drum falls on to three inclined grids or shakers, which are reciprocated by a three-throw crank-shaft, so arranged that the shakers, while tossing the straw and thus releasing any entangled grain, slowly work it out at the end of the machine, where it falls on to the strawboard ready to be carried away for farm use; any grain passing through the shakers is received on a vibrating inclined board, down which it slides to the other grain coming from the concave.

1528. Beater bars and drum ends for thrashing machine. Contributed by J. Goucher, Esq., 1862. M. 866.

These important details are usually made of malleable cast iron, so as to obtain sufficient toughness without entailing any great cost in manufacture. The beater bars are fixed longitudinally on wooden bars that connect the drum ends shown, and the complete drum revolves at about 1,000 revs. per min., close to the "concave" or grid, between which and the drum the straw to be thrashed is fed.

The form of bar shown was patented in 1848 by Mr. Goucher, and has now become universal. On its face are diagonal channels which reduce the breakage of the straw and grain, probably owing to the certainty with which the straw is carried round and the clearance spaces provided for the grain. One of the bars has been bent to show the toughness of the metal employed.

1529. Model of corn screen. (Scale 1 : 4.) Lent by R. Boby, Esq., 1898. M. 3016.

This machine was patented by Mr. Boby in 1855, but some of the details are later improvements; it is used for separating thin grain and dust from corn, so as to obtain a uniform product.

The machine consists of a sieve, sliding on guides inclined at an angle of 13 deg., upon which it is reciprocated by a rapidly rotated crank-shaft. The corn, from a hopper above, is passed through a distributing box that delivers it at the top of the screen, with the result that the smaller seeds drop through the meshes of the sieve into a receptacle below, while the larger ones pass off at the foot. The screen itself is detachable so that the grade can be altered; that in the model is of an actual mesh, so that this model machine is suitable for use in testing samples of grain.

To prevent the screen from being choked, there are, fixed below it to the stationary framing, transverse rods upon which are strung loose washers that project up between the wires of the screen, so that when the screen is in motion these washers keep the intervening spaces clear. The wire rods of the screen are of rectangular section, but have rounded top edges to assist the smaller grain into the spaces.

FOOD-PREPARING APPLIANCES.

In nature, food is but rarely obtained in the state in which it is best fitted for consumption by man or other animals. In the case of horses, some experiments of the London General Omnibus Co. give quantitative results: it was found that by cutting the hay a saving of 23 per cent. was effected in the consumption; that crushing the oats reduced the consumption 15·8 per cent., and that by these two changes the cost of feeding a horse was reduced 2·5*d.* per diem, owing to the more perfect assimilation of the food consumed. Probably with other animals similar results would be obtained, while with man cooked food has become almost essential.

Stable Machinery.—In the preparation of the food for animals, roots such as turnips are now frequently washed and then cut into slices by a revolving disc provided with cutting blades resembling plane irons. The roots placed in a hopper slip down the inclined interior and continually feed themselves towards the disc as the cuttings are removed. Such machines are, however, being superseded by a modified form known as a pulper, in which the knives are replaced by projecting teeth which tear pieces off in a form that is very convenient for mixing with cut forage or other food.

Forage or chaff cutters are machines by which hay, &c., are cut into lengths of from ·2 to ·7 in.; this is usually done by revolving knives, while the material is being fed forward by rollers (*see* No. 1530). Machines of this description are sometimes fitted to thrashing machines for dealing with the straw, and they are also used for cutting up ensilage.

Crushers are chiefly used for bruising corn and beans, and for breaking up linseed cake. For the former purpose they

consist of two large smooth rollers or else a pair of smaller ones fluted; for crushing cake intersecting teeth projecting from revolving cylinders perform the reduction (*see* No. 1531).

Dairy Appliances.—These chiefly consist of devices by which the time or labour required to convert milk into butter or cheese is reduced; the purifying and cooling of the milk has also received attention. The separation of the cream, which for thousands of years was done by the slow gravitation method, known as allowing the milk to stand, is now being rapidly superseded by the use of centrifugal machines (*see* No. 1533). The churn, probably the oldest dairy appliance, has been developed from the skin bag churn to the more rapid and convenient forms now in use, chiefly of a barrel shape in the largest sizes. A dairy appliance that has in recent years been greatly simplified is the press by which cheese is consolidated by a sustained pressure; the pressure is applied by a screw, but is maintained by a lever arrangement that also regulates it.

Flour Mills.—The earliest method of reducing corn to flour was with a pestle and mortar, represented by a pair of stones concave and convex or by a hollowed log and a club. The hand quern succeeded these and acted like our present millstones by a circular grinding action; increased in size and driven by power, the nether millstone became our "bedstone," and the upper one the "runner"; in some modern mills, however, the stationary stone is the upper one. The meal from the stones is usually dressed or sifted through screens so as to remove the bran which in passing between the stones is only reduced to flakes of considerable size.

Within the last 20 years the use of millstones in the production of the whitest flour has been almost entirely superseded by roller-milling and the gradual-reduction process, in which the corn is reduced to flour between rollers by a series of stages. The grain is passed successively between pairs of chilled cast-iron rollers, of about 10 in. diam. by 30 in. long; each pair is set closer together than the preceding, and after each passage or cracking the product is screened or "bolted" so as to separate the flour reduced. In this way the flour from the successive layers of a grain of wheat are obtained considerably classified, and the market value of the highest qualities is such as to render the separation profitable.

In all mills the flour dust in the air will burn explosively under certain conditions, so that the collection and removal of this dust becomes an important matter. Settling-rooms have been generally employed, but a more recent dust separator is seen in No. 1541.

Cooking Appliances.—Grates are now generally so constructed as to utilise much more of the heat than was the case with the open roasting fire, the flames being carried through flues round the ovens and boilers in a systematic course. Oil and gas stoves are also modern improvements in cooking that

are very extensively employed, chiefly owing to their convenience and ready control, while electrical heating is even more convenient, but at present is far too expensive for all but special purposes. Cooking or baking by high temperature steam is done in certain large undertakings, while the increased solvent action of water boiling under a pressure of several atmospheres, as in Papin's digester (*see* No. 1559), is utilised in many manufactures as well as in food preparation.

1530. Model of chaff-cutter. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2683.

This model was shown at the 1851 Exhibition and represents a machine introduced in 1844 by which forage for horses is cut into short pieces resembling chaff. It consists of a horizontal trough for receiving the uncut forage, which is moved by hand towards a pair of fluted feed rollers that force it through the mouth of the machine. Here two revolving knives attached to a flywheel cut off the material fed through, twice every revolution. Pressure is applied to keep the material compact at the mouth where it is being cut, the upper roller and a sliding block being continually pressed downwards by a lever and weight arranged under the trough. The flywheel is directly rotated by a winch handle, but additional power can be applied by another winch which is connected to the former by a bevel gearing and a clutch. The feed motion is derived from the flywheel shaft by spur gearing, and two rates of feed can be obtained by the use of a sliding pinion. This machine has since been altered by the use of blades sharpened on the convex edge, and by the introduction of an intermittent feed, while the use of worm gearing has also simplified the mechanism.

1531. Model of oilcake crusher. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2684.

This model, shown at the 1851 Exhibition, represents a machine introduced in 1841 for breaking up oilcake into small pieces suitable for feeding cattle or for reducing it to a powder for use as manure. It is driven by a winch handle attached to a flywheel that drives the lower pair of rollers which are fluted, and by reducing gear also drives, the upper rollers which have intersecting teeth. The distance between the rollers is in each case adjustable by sliding bearings, and the spaces between the cogs of the upper rollers are cleared by fixed scrapers.

1532. Bone mill. Woodcroft Bequest, 1903. M. 1657.

This is a small example, made in 1867, of the type of machine used for breaking bones into fragments, so as to render them suitable for use as manure or for converting into animal charcoal. The work is performed by two revolving cylinders, provided with projecting teeth which overlap but, being in different planes, do not interfere.

These rollers are built up of steel discs, resembling milling cutters, so threaded, with intermediate distance pieces, on the axles that the discs on one roller are opposite the distance pieces on the other. The axles are externally geared together, and are driven at a high speed, through gearing, from winch handles with flywheels. The bones are fed into a hopper above the rollers and, as reduced, fall into a drawer below.

In power-driven machines of this kind there is usually a slipping arrangement in the mechanism, which prevents damage when, through the presence of iron or similar material, the safe load of the machine is exceeded. A revolving screen is also added to separate the product into grades.

1533. Cream separator. Presented by Messrs. Watson, Laidlaw & Co., 1902. M. 2331.

When milk is allowed to remain stationary for many hours, the cream contained in it gradually rises to the top, owing to it being somewhat less dense than the rest of the fluid, and is then collected from the surface by skimming. It is now, however, customary to perform this removal directly by a centrifugal machine, in which the separation due to the difference in density is promptly and continuously effected by centrifugal action.

The machine shown was patented in 1888–95 by Messrs. J. Laidlaw and J. W. Macfarlane, and is of a size suitable for working by manual power. The milk to be treated is placed in an attached open reservoir, from which it passes to a stationary cylinder at the top of the machine, fitted with a float which automatically regulates the flow to suit the capacity of the apparatus. From this cylinder the milk passes into a distributing cup, fitted into the top of a revolving inverted truncated cone, and through small holes in the circumference into the chamber below; the heavier portion, or skim-milk, collects around the conical sides, having forced the cream it contains into the central region. Two vertical radial diaphragms with grooves on their inner edges lead this cream to two radial passages from which it flies off into an annular channel which leads to the cream outlet; the skim milk passes through the cone into a lower chamber having a central outlet which retains a large body of milk in the cone, but permits discharge as fresh milk is fed in.

The separator shown is for treating 15 galls. of milk per hour, while the handle is turned at the rate of 56 revs. per min., this causing the cone to make over 10,000 revs. per min., the total ratio of the gear employed being 1 : 184. The gear is all cut and is of the bevel and spur wheel type; but, on account of the great amount of energy accumulated in the revolving masses, the winch handle is connected to its shaft by a form of ratchet drive, which allows the shaft to run forward free of the handle. Owing also to the high working speed the lower end of the central shaft rests on a ball pivot, while the upper bearing is carried in a notched washer of india-rubber, by which arrangements easy running is ensured.

The internal construction of the machine is shown by a full-sized sectional drawing; a similar drawing shows another form of this machine in which epicylic gear is introduced into the train.

1534. Churn. Contributed by Sir B. Samuelson, 1860. M. 609.

When introduced, this was known as an atmospheric churn on account of the separation of the butter being assisted by the large amount of air that the machine forced through the milk. It consists of a rectangular box fitted with a horizontal axle on which are secured four radial paddles, the paddles being alternately solid and perforated. The cover of the churn is provided with two handles, which are hollow and so serve also as air passages.

1535. Churn. Presented by Messrs. Woolf & Co., 1894. M. 2672.

This is a portable form of atmospheric churn, patented by Mr. H. Clifton in 1865. It consists of a vertical tin cylinder, within which freely slides a disc or piston. The piston is fitted with a tubular rod, terminating in a cross handle, by which it may be reciprocated. A removable cover closes the vessel and prevents splashing. The disc and the rod are extensively perforated, and through the holes jets of air or milk are forced when the apparatus is worked. With a stroke of 6 in. and at the rate of about 60 strokes per min. the butter is extracted in 10 or 15 minutes. Larger churns of this type are constructed with a crank motion for driving.

1536. Churn. Lent by the Disc Churn Co., 1894. M. 2673.

This is a form of churn, patented by Mr. J. H. H. Duncan in 1891–2. It consists of a box containing a sharp-edged wooden disc capable of being rapidly rotated by hand about its horizontal axis, through external spur

gearing having a ratio of 6 : 1. The top cover has two internal ribs projecting downward, one on each side of the disc; the motion of the disc, and the continual projection of the milk against the cover and casing, break up the envelopes of the fat cells in the cream and liberate and collect the butter. The butter-milk is run off by an outlet at the bottom of the churn.

The specimen shown has a capacity of one gallon and is fitted with a glass front to show the construction.

1537. Model of conical flour mill. (Scale 1 : 4.) Presented by H.R.H. Prince Consort, 1857. M. 19.

This represents a flour mill patented by Mr. Walter Westrup in 1850. It has two pairs of stones arranged on a single vertical shaft; in each set the lower stone is the runner and is somewhat conical with the smaller end uppermost, while the bedstone is annular and bevelled to fit. Between the two mills is a cylindrical drum, with gauze screens, acting as a dresser into which the meal from the upper mill is delivered, the flour passing off while the coarser meal falls down into the lower mill where the grinding is finished.

In the actual mill the runners were 30 in. diam., and are stated to have been capable of grinding twice as much flour as a pair of ordinary 4 ft. stones, while only $\frac{1}{10}$th of their weight. This successive grinding with intermediate screening is the leading feature of modern milling: even with this two-stage mill it was found that the loss by middlings was reduced by this treatment.

1538. Model of roller flour mill. (Scale 1 : 24.) Presented by Messrs. Thomas Robinson & Son, 1903. M. 3271.

The time-honoured process of making flour by grinding wheat between millstones, so set as to produce in one operation a meal which by simple sifting could be divided into one or two grades of flour, and also be freed from the bran, remained in almost universal use till early in the 19th century, and is now known as low milling. The modern gradual-reduction, or high milling, process has developed from attempts, chiefly made in Hungary, to obtain a finer and whiter flour by breaking down the grains of wheat in successive passages between ordinary millstones, and collecting the product from each stage separately, so that the flour from the whitest portions of the grains should not be darkened by that from other portions. In this way it was proved that the average price of the graded products was higher than the price obtained for the average product produced by low milling. This change of system resulted in the introduction, amongst other improvements, of the use of metal rollers in place of millstones for cracking and crushing the grains—a method which had been tried in 1820 at Paris and in 1829 in Switzerland, but was first successfully adopted in 1867 at Budapest. The introduction of high milling into England was very gradual, and it was not till 1879 that at Bilston the first complete and automatic gradual-reduction mill was erected in this country. Since then, however, the conversion from low to high milling has been remarkably rapid.

The building of the complete roller flour mill represented in the model is divided into two sections by a vertical fireproof wall, which separates the **wheat-cleaning department,** in which a dusty and somewhat inflammable atmosphere exists, from the flour-milling department, in which the reduction takes place.

The corn, as unloaded from a vessel or wagon into the cleaning department, is delivered into the receiving hopper, from which it is directly raised by a vertical elevator into storage bins at the top of the building, where there is a horizontal worm conveyor to deliver the corn into the desired bin. Under each bin is a mixing conveyor, whereby its wheat can be drawn off in any required proportions, and then elevated to the cleaning machines, in passing through which the grain is automatically freed from foreign seeds,

stones, and other impurities, and is scoured, washed, dried, brushed, and thoroughly cleaned. It is then again carried by an elevator to the top of the building, from whence it is delivered by a shoot through the partition wall into the cleaned wheat bin.

The **flour-milling department,** into which the cleaned wheat passes, has in its basement the main shafting and the bottoms of the elevators by which the product from the roller mills, which are on the first floor, are conveyed to the top of the building for distribution by gravity to the flour dressing and purifying machines. The two break roll mills on the roller floor gradually break the wheat so as to release the semolina and middlings which, after being purified from the dark flour thus obtained, are reduced to flour in two smooth roll mills on the same floor. The purifying floor carries the chief machines by which the products from the roller mills are classified during the process of gradual reduction. The top, or dressing floor, contains the rotary sifters and dressers, which separate the products of the break rolls; also the centrifugal dressing machines by which the reduced semolina and middlings are dressed into fine flour ready for the delivery into sacks, while the bran, offals, and germs, separated by the dressing machines, are delivered into other sacks.

The mill represented is capable of producing about two sacks, or 560 lbs., of flour per hour when driven by an engine indicating 20 H.P.; this power is applied to a lay-shaft in the basement, from whence it is transmitted by belting and some shafting to the entire plant.

1539. Conveyor. Lent by the Anti-Friction Conveyor & Grinding Machinery Co., 1890. M. 2298.

Screw conveyors have for many years been the favourite means for moving granular materials horizontally in milling, cement-making, and similar industries, but the screws employed have previously been complete blades, the whole surfaces of which were continually being forced through the grain. By the employment of the helical wire form shown the frictional resistance is greatly reduced, the conveyor only acting on the outer layer of grain which carries along the inner portion as if it were in a moving jacket. Two forms of section for the helix are shown, the stronger T section being required for conveying very dense materials.

1540. Model of swinging conveyor. Made in the Museum from particulars supplied by G. F. Zimmer, Esq., 1900. M. 3025.

This machine for conveying granular material was patented by Herr Eugen Kreiss in 1890; it is of the vibrating trough class and, having no pushing element, can be employed on materials which deteriorate by handling.

The trough is suspended by links or is supported by flexible legs in an inclined position, as shown in the model, and is rapidly reciprocated by power from a crank-pin. The swing is, however, confined to one side of the vertical line through the point of suspension or support, so that in the forward portion of the swing the conveyor is rising, while it is sinking during the return stroke. During the forward stroke the material is moving forward and upward, but while it is falling again, the trough is returning to the initial position ready for another forward stroke, so that the material has a continuous forward motion.

The arrangement will work upward with the trough at a considerable angle; with a downward slope of 1 in 20 the capacity is about 10 per cent. greater than with the trough horizontal. On account of vibration, the maximum capacity of this conveyor has been found to be about 10 tons per hour moved to a distance of 50 ft.; but, by balancing one conveyor against another, as patented by Mr. Zimmer in 1900, it becomes possible to convey 150 tons per hour to a distance of 500 ft.

1541. Model of cyclone dust collector. (Scale 1 : 4.) Lent by Henry Simon, Esq., 1890. M. 2322.

This is an apparatus for removing and depositing the large quantity of dust raised in grinding and similar operations. By a centrifugal fan or a steam jet the dust is drawn in with a large volume of air and discharged into the cyclone, when the dust escapes through the orifice at the base of the machine while the purified air issues at the top. The apparatus consists of a conical sheet-iron chamber into which the dust-laden air enters at a high velocity through a wind trunk opening tangentially into the cone so that a vortex is set up. The heavier solid particles fly to the side of the cone, where their velocity is destroyed by the friction and they slide down the side to the vertex where they escape, while the pure air in the centre issues through the large central opening at the top. Spiral ribs fixed inside the case assist the downward motion of the dust particles.

1542. Model of blending and sifting machine. (Scale 1 : 4.) Lent by Messrs. Joseph Baker & Sons, Ltd., 1908. M. 3527.

Better bread results generally from a blend of different qualities of flour rather than from a single quality only. This machine, patented by Messrs. G. S., J. A., and W. R. Baker in 1892–97, blends and sifts the mixture automatically; the sifting process is necessary owing to the fineness and density of flour, which causes it to become compact.

The machine consists of a cylindrical hopper with one fixed and two (or more) radial partitions which can be set, by graduations on the edge, to divide the area in any desired proportion. The bottom of the cylinder is a screw blade of one turn of short pitch rotated from shafting by worm gear. This blade cuts off from the columns of flour a slice which is delivered by scoops on the underside of the blade to the sifter. The latter, which is hung just below the floor, consists of a semicircular wire sieve at a slight inclination which can be adjusted. On the inner surface, oscillated by a connecting rod through a universal joint, is a frame which sweeps the flour to and fro over the sieve; the clearance can be adjusted by screws. The sifted flour falls into a hopper with a canvas shoot, while any foreign matter works down the sieve into a tailings box.

1543. Mixing and kneading machine. Presented by Messrs. Werner, Pfleiderer, & Perkins, Ltd., 1908. M. 3556.

This is a small example of the mixing and kneading machine patented by Mr. P. Pfleiderer in 1875, 1878, and 1895. It consists of a chamber, the bottom of which is formed as two cylindrical surfaces, containing two parallel shafts carrying the kneading blades, which during their revolution sweep the entire surface. The blades form approximately portions of elliptic discs, set obliquely to the axes, with the ends cut off so that they sweep over the ends of the chamber, and with large asymmetrical portions removed to give clearance for the material. The shafts are geared together and revolve at different speeds in the ratio of 6 : 13. The machine is easily taken to pieces by removing four clamps, when the upper part of the chamber may be lifted off and the shafts taken out. It has a capacity of 1 to 2 lbs., and may be driven by hand or power.

1544. Model of mixing and kneading machine. (Scale 1 : 4.) Lent by Messrs. Joseph Baker & Sons, Ltd., 1908. M. 3528.

This machine is for mixing the ingredients and kneading the dough in bread making; it embodies improvements patented in 1892 by Mr. G. S. Baker.

There are two pairs of kneading arms which revolve in cone bearings in a container shaped to the cylindrical surfaces swept out by the arms. The latter are of helical form, looped at the end, the shape and section being empirical. The action obtained is that of folding and pressing the dough while bringing it from the corners to the centre of the container. The members of each pair are geared together through an intermediate wheel so as to revolve in the same direction. The two pairs revolve in the same direction, but by claw clutches a wheel can be inserted in the train of one pair so that they revolve in opposite directions. With the clutches out of gear one pair remains stationary. There are two speeds for all three motions obtained through a cone friction clutch on an intermediate shaft. The higher speed is for incorporating the ingredients, and the lower speed is for kneading.

The container can be tilted forward on the axis of the intermediate wheel by toothed segments, either by power through wedge gearing put into action by an eccentric shaft, or by a hand wheel through worm gear; the driving pulley can also run loose, the connection to the driving shaft being by a cone clutch.

The size represented is for mixing and kneading with ingredients two sacks of flour (*i.e.*, 560 lbs.).

1545. Fruit-paring machine. Contributed by G. Kent, Esq., 1860. M. 618.

By this machine, patented by Mr. D. H. Whittemore in 1856, an apple is pared and then cut into a continuous spiral, the core only remaining intact. The fruit to be acted upon is placed on a three-pronged shaft which is rotated in fixed bearings by hand, and has on it a quick-pitched screw which traverses a tool-holder that slides on a circular guide. The paring tool is a guarded circular knife resembling a spokeshave, and by a spring is held in contact with the revolving apple. When the paring tool has finished its cut the direction of rotation is reversed, so that the tool-holder moves backwards; a second tool, consisting of a vertical blade, is then pushed into action, and makes a deep spiral cut, while an extension of the blade horizontally cuts the spiral from the core.

1546. Fruit and vegetable paring machines. Woodcroft Bequest, 1903. M. 1641.

(*a*) This, the largest of the four machines, is by Mr. Bennet Woodcroft and is an experimental apparatus with which some good results were obtained, but its general construction is too expensive for ordinary domestic use. The fruit is held between two revolving centres which are simultaneously closed together by a right and left handed screw contained in the bed; a long shaft rotates the two headstocks and at its centre drives a worm that slowly turns a wormwheel carrying an adjustable tool-holder. The tool is of the guarded knife construction and is forced outwards from the holder by a spring so that as the holder is moved round in a horizontal circular path only a thin uniform paring is removed. A swinging arm carries a wheel that can gear with either of three different wheels so as to adjust the rate of circular feed.

(*b*) This machine was patented in 1863. In it the fruit to be pared is carried on a horizontal axis which by a handle is swung round a vertical centre. The base of the machine, which clamps to a table, has a circular rack which by spur gearing rotates the spindle as the handle is moved. A guarded knife swinging vertically does the paring and is kept in contact with the fruit by a radial spring.

(*c*) This parer acts similarly to (*b*), but is driven by the continuous rotation of a winch handle. When the paring knife reaches the limit of its travel it returns under the action of a spring to its starting position, owing to the omission of four of the teeth from the last driving wheel.

(*d*) This was patented in 1876. The fruit is carried on a horizontal axis, that terminates in three prongs and is driven by spur gearing. By bevel

gear, a wheel containing the tool-holder is rotated round a horizontal axis at right angles to the former one; the tool-holder, which is in the form of a swinging arm, is controlled by a cam at the back of the bevel wheel, but the cutter, which is a guarded knife blade, is kept in contact with the fruit by a spring. There is a fixed stationary blade that cuts down to the chuck, and there is a swinging arm driven by a cam on the bevel wheel which forces off the peeled apple at the completion of the operation.

1547. Sugar cane mill. Lent by Messrs. Fawcett, Preston & Co., 1907. M. 3485.

This small three-roll mill for crushing sugar cane embodies features patented in 1871–6 by Mr. L. Rousselot. The two lower rolls are in bearings held together with housings by through iron bolts. The top roll is held down in the housings by similar bolts permitting the removal or adjustment of a roll independently of the rest. The delivery table, trash shoot, and juice spout are shown.

1548. Model of sugar cane mill. (Scale 1 : 8.) Lent by Messrs. John McNeil & Co., 1903. M. 3210.

The oldest, yet still the most common, method of extracting from the sugar cane the juice from which sugar is afterwards prepared is by passing the cane between crushing rollers. The earliest type of cane mill had two vertical rollers driven by animal power, but the form now generally adopted is that having three horizontal rolls geared together and driven by heavy intermediate reduction gearing from a reversible steam engine.

In the example shown, however, the mill has, in addition to the usual three rolls, a pair running at the same speed—an arrangement patented in 1882–7 by Messrs. J. Thompson & J. Black. By these additional rolls the work to be done, which is very severe, is more distributed, a result attained in large installations by the use of two or more three-roller mills in series. Usually the single pair of rolls which commences the crushing is coarsely fluted, the top and one of the bottom rolls of the set of three are finely fluted, while the other bottom one is plain.

1549. Model of sugar-chopping machine. (Scale 1 : 4.) Contributed by J. S. Mason, Esq., 1861. M. 630.

By this machine the loaf sugar is split into the small cubical pieces ordinarily used. The chopping is done by a pair of blunt blades, the bottom one being fixed and the upper one rapidly reciprocated in vertical guides, by connecting rods from a crank shaft below, driven by a treadle. The larger pieces are split by plain blades at one end of the machine and then finally reduced by crossed blades, but in neither case do the blades close together.

1550. Sausage-making machine. Contributed by Messrs. S. & E. Ransome & Co., 1862. M. 623:

This machine, patented by Mr. A. W. Hale in 1859, consists of a case with a knife blade projecting upwards along the centre. On each side of the blade is a helically-fluted pinion, the two gearing together and carrying the meat from the hopper above, down on to the knife. Inclined ribs in the case and the screwing action of the pinions carry the meat along, so that while being minced it is at the same time being pressed out of the end of the casing where is fitted a skin for its reception. The machine opens on a hinge to facilitate cleaning.

1551. Model of coffee roaster. (Scale 1 : 8.) Contributed by Messrs. Dakin & Co., 1858. M. 142.

This machine, which was patented in 1848 by Mrs. E. Dakin, is for roasting coffee berries, a treatment that gives the flavour and colour to the

beverage. It consists of a metal cylinder carried on a hollow horizontal axis and rotated by a chain wheel; it is capable of being easily pushed into a furnace-heated jacket, owing to the front end of the cylinder being supported by a truck running on overhead rails. Direct heating of the cylinder is avoided on account of the risk of burning the contents. Through the hollow shaft a "taster" is inserted by which a few berries can be withdrawn to test the progress of the roasting. When the roasting is completed the cylinder is withdrawn, a segmental slide on its surface opened, and through this opening the berries are discharged into a receptacle below. A clutch is fitted to the chain wheel for stopping the motion when desired.

1552. Bachelor's stove. Presented by J. G. Watt, Esq., 1863. M. 942.

This is a compact cooking apparatus, comprising a grate and chimney, a stewpan and a water-kettle, and was probably designed by James Watt, who used it for cooking the irregular meals that he took in his workshop or study.

Both cooking utensils have large heating surfaces, and when in use are air-jacketed to the top. There is an upper ring which supports the utensil in use, but by lowering the stewpan into the chest first, the whole apparatus can be closed up compactly: the chimney also can be stowed inside.

1553. Turnspit and appliances. Received 1904. M. 3361.

The original form of the spit, for supporting meat while being roasted, was doubtless a stake or skewer resting on supports, or dogs, and to it was subsequently added a winch handle to facilitate turning for the purpose of ensuring equal heating. As early as the 15th century, however, weight-driven mechanism was in use to obviate the continuous labour and attention required in turning the spit, and the arrangements shown, which are from the West of England, are of this type, although probably made in the 17th century.

The turnspit consists of a frame carrying a barrel upon which is wound a rope whose free end is connected to a driving weight, the travel of which was sometimes reduced by the use of pulley blocks. The axle of the barrel is hollow and terminates at its outer extremity in a squared end to receive the winch handle by which the weight was wound up; within this axle is a smaller one terminating at the outer end in a grooved pulley over which passes an endless rope or chain connecting it with a smaller pulley on the spit. The axle of the pulley is driven by that of the barrel through a ratchet mechanism which enables the rope is to be wound in rapidly. From the pulley axle is also driven, through spur and worm gear, a weighted flier, which serves as a flywheel in assisting the mechanism at times when lack of balance of the joint causes excessive resistance.

Two spits are shown, and the dogs have alternative crutches for supporting the spit. One of the spits has a fork piece secured by a thumbscrew, to serve as a driver for the joint; the other consists of a loop with two double bars secured to it by fly nuts, so as to form a cage for holding fowls and other small objects without transfixing them. The two pot-hangers have a rack and stirrup adjustment for length, and were supported from a beam across the chimney; for carrying a two-handled cauldron a pair of hinged hooks were provided. The remaining appliance is a bread girdle, consisting of a horizontal circular plate supported by a handle hinged to it.

1554. Weight-driven roasting jack. Presented by A. S. D. Arundel, Esq., 1900. M. 3138.

The necessity of turning a joint while being roasted early led to the invention of appliances for this purpose, particularly as the long fires in use

having suggested the employment of horizontal spits, the weight, unequal balance, and considerable frictional resistance made the work of turning much more difficult than would appear from modern arrangements.

At first the spit was rotated by hand, probably intermittently, but at a very early date the use of a spit dog was common in large kitchens, the animal being placed in a drum which it kept revolving by running up the inside surface. In such kitchens, however, with big fires the current of hot air up the chimney was found to be sufficient to drive a form of windmill, which, by gearing, was connected to the spit, and this arrangement, known as a smoke jack, was largely adopted. For smaller fires it proved unsatisfactory, with the result that early in the 18th century the weight-driven jack became general, and was then known as the "common" roasting jack.

The remains of the jack shown, together with the attached drawing, explain the complete arrangement. There is a weight drum fitted with a winch handle by which the weight—often arranged outside the building to give longer travel—can be wound up, and this drum has a pawl engaging with a train of wheels controlled by a combined fan and flywheel. The air resistance exerts a governor action while the momentum of the flywheel serves to overcome the extra resistance due to the lack of balance of the load on the spits, which are connected to the driving mechanism by endless chains.

1555. Horizontal turnspit. Presented by W. C. Benedict, Esq., 1904. M. 3363.

The application of a spring-driven train of wheels to the driving of a horizontal spit appears to have been carried out in the 16th century, but the example shown was made about 1820, and connects the weight-driven jack with the spring-driven bottle jack.

The arrangement consists of an iron case containing the train of wheels which rotate two spindles in the ratio of about 2 : 1; to either of these spindles can be fitted a clamp holding one end of a large horizontal skewer or spit, supported at the other end by an iron dog (missing). A fly, consisting of an arm with two heavy balls and driven by a worm, is provided in the base of the case, to equalise the motion if the joint be not balanced on the spit. At every revolution a wiper causes a hammer to strike a bell so that it may be known when the spring has run down.

1556. Roasting jack. Received 1896. M. 2937.

This roasting jack was made about 1750, but the arrangement adopted is much earlier. It is intended to stand over an opening in the mantelshelf through which descends the cord supporting the joint. The cord is continuously rotated by a spring through a train of wheels controlled by a fan brake, but a fusee is introduced to equalise the action of the spring. Friction is reduced by a live ring of three rollers, that supports the collar carrying the weight of the joint.

1557. Roasting jack. Presented by J. Dickinson, Esq., 1896. M. 2963.

This is a spring-driven bottle jack with a verge escapement, and represents the arrangement most commonly employed. The escape wheel gives a vibrating motion to a vertical shaft on which are the two pallets, and this shaft carries a toothed sector engaging with multiplying gear which rotates the hook supporting the joint. The weight of the joint is carried by a number of silk threads from the stationary hook above so that collar friction is avoided. The joint is rotated three times in each direction for a double beat of the escapement.

1558. Roasting jack. Presented by W. Robinson, Esq., 1870. M. 1208.

This jack, patented by Mr. W. Robinson in 1865, has a spring-driven clock-train terminating in a crank. The hook of the jack is attached to a screwed vertical shaft on which slides a nut that is connected to the crank-pin, the arrangement resembling an Archimedean drill but acting as an escapement; the joint is rotated four turns between each reversal.

1559. Papin's digester. Woodcroft Bequest, 1903. M. 520.

This is a modern form of the apparatus invented by Dr. Denis Papin about 1680, when it was described by him as "a new digester or engine for softening bones." John Evelyn in his "Diary" describes with much appreciation a supper at the Royal Society in 1682, cooked by this apparatus.

The digester consists of a strong boiler provided with a removable cover and a safety valve; this is believed to have been the first application of a lever-weighted safety valve to a steam boiler. The high temperature of the water boiling under the high pressure attained causes it to exert a very solvent action on any bones, &c., immersed in it.

CLEANING AND WASHING MACHINERY.

The mechanism of such machinery is generally simple, and in nearly all cases consists of arrangements by which rotary motion is substituted for the reciprocating movements naturally resorted to when the work is directly done by hand. For cleaning roads, complete machines which collected and removed the refuse have been tried, but the general practice now is to use rotary brushes worked by horse power to collect the material and then to lift it by manual labour; the incessant variation in the consistency of the refuse is a factor that interferes with a completely mechanical collection, but this is now somewhat modified by systematic watering.

In laundry work the further application of machinery presents a field of great scope, for when it is considered that with most linen and cotton articles the total cost of their washing exceeds their first cost, the importance of laundry work is very evident, and with the improved efficiency in small motors the increase in the employment of laundry machinery will probably continue.

Carpet-beating is another cleaning process in which machinery has been extensively introduced. Instead of violently beating the carpet, it is passed through a machine in which it is exposed to jets of compressed air, which blow out the dust particles as they are released by a shaking motion given to the piece as it slowly passes over the row of jets. A pneumatic system in which the dust is drawn from carpets, &c., through a pipe connected with a portable pump driven by hand or by a petrol motor, is now being extensively used. This method enables the cleaning to be effected without removal, and is especially valuable in the case of railway-carriage or similar upholstery.

1560. Model of street-sweeping machine. (Scale 1 : 8.) Contributed by Messrs. Joseph Whitworth & Co., 1857. M. 104.

This represents a machine, patented by Sir J. Whitworth in 1840 and 1842, for sweeping streets and at the same time delivering the dirt into a low cart specially made for the purpose. It consists of a pair of endless chains with bars between them, carrying brushes up an inclined plane at the tail of the cart. The brushes move faster than the cart travels forward, so that they brush the mud forward, and up the incline into the well of the cart. Many of these machines are made and used, but as they had to compete with pauper labour they could not show any considerable economy.

1561. Model of early washing machine. Received 1861. M. 683.

This represents a machine patented in 1782 by Mr. H. Sidgier. It consists of a rectangular water tank, in which is immersed a horizontal open-jointed drum built up of staves which have a ribbed interior surface; two of the staves are removable so leaving an opening by which the clothes are placed in the drum. By a central disc the drum is divided into two compartments, in one of which are small knobs of copper and in the other small stones, these heavy particles being intended to assist the washing by their rubbing action as the drum is rotated. The drum is driven by friction from an upper shaft; in the specification drawing the drum is arranged to run faster than the driving shaft, instead of going at half the speed as in the model. The model suggests that the fresh water was introduced through the axle of the drum.

1562. Model of washing and wringing machine. (Scale 1 : 4.) Contributed by T. Bradford, Esq., 1861. M. 684.

This machine, patented by Mr. Bradford in 1857, consists of a washing machine and a pair of wringing rolls, mounted in a metal framing.

The washer is in a form of a rectangular box, provided internally with projecting ribs and closed by a cover that projects inwards and so increases the internal irregularity. The box is carried by end trunnions, which, however, are not in the centre; they each carry two projecting lugs which, striking upon spring buffers, limit the rotation of the box to an angle of 150 deg. By a handle at one end, the box is swung backwards and forwards between the stops, so violently shaking the contents of the washer and thereby cleaning the clothes. The used water is run off by a plug hole at the bottom.

The wringer consists of a pair of wooden rollers of equal diameter, geared together and driven by a hand flywheel through powerful spur gearing; the bearings of the upper roller slide loosely in the housings and are pressed downwards by weighted levers.

1563. Model of wringing machine. (Scale 1 : 4.) Contributed by T. Bradford, Esq., 1861. M. 685.

This machine has three equal horizontal rollers geared together and carried in vertical standards; the lower roller is in fixed bearings and by a hand flywheel is slowly driven through gearing. The bearings of the other rollers are free in the housings, but those of the top roller are powerfully pulled downwards by weighted levers so that the rollers are continually pressed together. By the three-high arrangement of rolls, the work passed from the lower pair is returned between the upper pair, without any reversal of the motion of the flywheel.

1564. Model and drawing of hydro-extractor. (Scale 1 : 8.) Lent by Messrs. T. Broadbent & Sons, 1891. M. 2390.

This is a machine, patented by Mr. T. Broadbent in 1875, for rapidly expelling water from saturated materials by centrifugal action. It consists

of a strong open-topped wire cage capable of rapid rotation on a vertical axis and provided with a large strap brake for speedily stopping when the drying is completed. The cage is enclosed in a casing, which below carries the bearings and a small direct-acting steam engine by which the necessary speed of from 700 to 1,200 revs. per min. is obtained. By so driving the use of belting is avoided, thus enabling the machine to be more quickly started and an unobstructed opening for charging is secured. Owing to the high speed and the probability of the charge being imperfectly balanced in the cage the whole machine is carried by three suspension rods on which it freely swings without transmitting its vibrations to the ground.

1565. Model of cask-cleaning machine. (Scale 1 : 8.) Presented by G. C. Potts, Esq., 1858. M. 171.

This machine, patented by Mr. Potts in 1857, consists of a frame in which the cask is mounted obliquely. The frame is carried on horizontal trunnions and is rotated, so causing water placed in the cask to scour the interior.

MACHINE TOOLS.

In this section have been collected the various machines and appliances employed in working metal or wood into the innumerable forms required in constructive work. Such appliances frequently bear some resemblance to the earlier hand tools, but though simpler to work are invariably more complicated, the greater perfection in the machine tool taking the place of the skill and close attention otherwise required of the workman. Even with hand tools it will generally be observed that the more simple the tool the greater the skill required to obtain expeditiously a good result with it.

There are two distinct features in machine tools that have each promoted the rapid development and extension which took place during the 19th century: the first is, that they do their work almost entirely by the forces of nature without animal labour, and so are practically without any limits of size or of physical endurance; steam hammers, metal-rolling or shearing machinery, and large cylinder boring machines are examples of this unlimited power and endurance. The second feature is, the speed and accuracy with which they attain any desired result, and this is due to the copying principle now to be found in all finishing tools.

Metal-working machine tools perform the desired alteration in the shape of the material either, by forcing it to flow into the required form, as in forging, rolling, and stamping, or the result is obtained by cutting from a larger mass those portions that are not required. In most work the first stage in the manufacture is accomplished by flowing and the final stage by cutting.

Casting arrangements have been included under *Metallurgical Furnaces and Appliances*, so that the remaining tools that perform their work by causing the material to flow into the required form are represented by hammers, rolls, and presses. As these tools are nearly always driven by steam power, there is

hardly any limit to the size of the work that they can be constructed to accomplish. When the "Great Eastern" steamship was proposed, however, the difficulty of forging her paddle shaft was felt to be serious until Nasmyth solved it by his steam hammer; the earlier "Great Britain" only avoided this trouble by using a propeller shaft built up of boiler plates with riveted joints.

In hammering tools, the copying principle is hardly applied, but in rolling and stamping the great saving in labour and time that it effects is fully seen. Cold stamping, from sheet metal into dies, is an extension of the method that is continually increasing in importance and applicability.

In machine tools that have a cutting action, such as lathes, planing and slotting machines, the full application of the copying principle is found. The earlier lathes could turn circular work, but to produce a parallel cylinder depended entirely upon the skill of the turner; by such tools the most expert man could hardly prepare a parallel shaft, and in the earlier engines it will be found that considerable ingenuity has been exercised in avoiding difficulties that only arose through the absence of true machine tools. The foundation of the modern finishing tools is the slide-rest, by which the cutting tool is supported and directed mechanically instead of by the unaided human hand. The greater command so obtained over the tool is of importance, as also is the means it affords for feeding the tool automatically, but the most valuable feature of the invention is that the care and labour originally spent in preparing the slides or guides is saved on every piece of work turned out by its aid, owing to the true lines contained in the rest being continuously copied on the work. Henry Maudslay fitted to the slide-rest a standard screw, through which, by change wheels, modified copies of this screw could at once be prepared on any work in the lathe. The introduction of the slide-rest was followed by the construction of self-acting tools in which the feeding of the tool into or along the work was performed entirely by the machine, so that when once adjusted the attention required from the workman was immensely reduced, while the speed and uniformity of the work turned out was greatly augmented. Further progress in this direction was made by the introduction of the turret lathe, and this has been followed by the development of the entirely automatic lathe, which produces, in large quantities, articles such as bolts and screws from the solid bar.

For the production of accurate machine tools the use of true planes is absolutely necessary; it was in 1840 that Sir Joseph Whitworth published his method of preparing such surfaces and for many years subsequently developed the subject, particularly as regards their application to machine tool production. A tool guided by two planes inclined together describes a straight line, and in all our lathes, boring mills,

planing, slotting, drilling, and shaping machines, such lines and planes are simply being copied on to the work in progress. With true planes, an accurately divided circle, and a correct screw of any pitch, perfect machines for rapidly finishing every description of mechanical work can, by the application of the copying principle, be constructed.

Drills and lathes are machine tools of great antiquity, but they remained very small and imperfect appliances until the introduction of the steam engine at the close of the 18th century. Then Messrs. Boulton & Watt, with their assistants, commenced the construction of large and heavy tools for engine-building, and from that time the growth of machine tools has been continuous. Planing machines (*see* Nos. 1619–20) are a much later development, and were followed by the shaping and slotting machines. Milling machines, in which a large number of cutting edges are continuously at work, like the teeth of a circular saw, are not of modern invention, although it is only during recent years that this type of machine has come into such extensive use. The great advantages of such machines are that, owing to the brief interval during which each edge is continuously cutting, the speed can be high without undue heating, and that very irregular shapes can be machined by their aid. The difficulty in sharpening such cutters has also been removed by the introduction of special tools for this work. Grindstones and emery wheels in their action are milling appliances, which, although slow cutters, have the great advantages of being able to act on hardened work, and of being self-sharpening.

In addition to the abstract copying that takes place in all machine tools the copying principle has been greatly extended by the introduction of machines in which an irregular pattern or template is used to control the action of the cutters (*see* Nos. 1597, 1654, and 1662–3).

Wood-working Machinery.—These tools are almost entirely of the cutting class, and closely resemble the corresponding machines for metal work; owing, however, to the small resistance of the material to severance the work done by the cutting edges is so light that the heat generated does not, as in the case of iron-working, impose a limit of speed on the cutter. Smooth cutting at a slow speed is, however, difficult, and appears to be only possible in all directions when the cutting edge is much guarded, as in a carpenter's plane or spokeshave, in which tools the guard is supporting the fibres. At a high speed such guarding is not required, probably because the cutting speed exceeds the splitting velocity. Owing to the soft and varying nature of the material, wood-working does not require the same degree of accuracy in its details as in the case of metal work, but in the machine tools employed no inferiority is admissible, the high speeds rendering the finest workmanship necessary. Circular saws are the most expeditious of wood-cutting machines,

but on account of the amount of material that they waste in sawdust are not suited for many purposes. For cutting up logs the frame saw, holding many thin blades and reciprocated vertically by a crank motion, is generally used, but the higher speeds possible with continuously running saws have led to band saws being employed also on this work.

Wood-planing machines usually finish the four surfaces of a board in one pass, the two sides and the top by cutters or blades revolving at a high speed, while the lower face may be dressed in the same way and finished by a fixed blade or plane-iron secured in the table of the machine.

Copying lathes for turning non-circular forms in wood usually do their cutting by high-speed revolving cutters while the work only slowly revolves, but in the small example in the collection (No. 1662), which is of French manufacture, a single fixed cutting tool is used. For cheaply producing balusters of a square section, the method now employed is to fix a great number of them between two face plates so as to form a cage, the large diameter of which leaves no appreciable curvature on the small faces of the individual bars; the whole set is then finished in four settings.

1566. Model of Vauloue's pile-driver. (Scale 1 : 24.) Woodcroft Bequest, 1903. M. 1784.

This early form of pile-driver was used in constructing old Westminster Bridge in 1739. The falling weight or "monkey" weighed 16 cwt. and had a fall of 20 ft.; the work was done by two or three horses, at the rate of from 100 to 150 blows per hour with an average fall of about 9 ft. An adjacent engraving shows the machine in operation.

The model, made by James Ferguson, F.R.S., represents, however, a machine that, owing to the limited floor space available, was driven by men turning a capstan instead of by horses. At the top of the capstan is a large spur wheel, gearing with a pinion that is on the shaft of a heavy crossed frame which acted as a flywheel, so that when the work was thrown off by the release of the monkey the inertia of this flywheel gave a temporary resistance that prevented the men or animals from falling. Above the spur wheel is a winding drum that contains the rope connected with the monkey, and above this drum is a small fusee drum that winds in a rope attached to an independent weight working in a guide tube. When the monkey rope was to run down, the driving peg that connects the drums with the spur wheel was forced upwards so releasing them, and under the pull of the small weight they ran back so assisting the unwinding of the monkey rope.

The monkey works in vertical guides and is in two portions, the lower piece being a free-falling weight while the upper portion pulls the rope down again after the fall, but the two portions can be used together when only a short fall is being given. At the top of the guides is a conical recess into which two levers at the top of the monkey enter, thereby being closed together, this causing them to release the lower portion of the monkey. The upper portion, however, in continuing its motion strikes a lever connected by a chain to the disengaging pin of the drum, which is thereby released so that the upper portion of the monkey runs down ready for the next blow; an independent lever prevents the driving pin engaging before the upper portion of the monkey has got home. It is probable that the machine generally worked on the shorter stroke without dividing the monkey.

1567. Model of pile-driver (working). (Scale 1 : 6.) Made by Messrs. Sissons & White. Received 1893. M. 2546.

This represents a steam pile-driving machine patented by Mr. W. Sissons in 1862. It has a timber platform 8 ft. square, carried on four castor wheels running on the temporary metals. On this platform is a similar one capable of turning on a centre attached to the lower one; this swivelling platform or turntable carries the boiler and machinery, as well as the guides and framing, but these guides are not adjustable except for batter. The monkey is lifted by a travelling pitch chain, into which a bolt is forced by an eccentric attached to the tripping gear within the monkey. The winch and sprocket wheel are driven by a vertical steam engine, through double purchase gear with one frictional connection, but the chain barrel is a single one and chiefly used for lifting the piles into position. An overhanging sheave on the crank-shaft provides for additional hauling, for use in moving or rotating the machine. The model also shows some piles with their shoes fitted and the driving hoop at the top to prevent splitting.

The machine is about 40 ft. high, and will pitch a pile 34 ft. long on the rail level. The monkey weighs about 1 ton, and the complete machine 7 tons. The monkey usually has a fall of 6 ft., and delivers 12 blows per min. The coal consumed is about 4 cwt. in 10 hours.

1568. Model of pile-driver (working). (Scale 1 : 6.) Made by Messrs. Sissons & White. Received 1893. Plate IX., No. 6. M. 2545.

This represents a steam pile-driving machine, similar to No. 1567, but having a greater range. It contains improvements patented by Messrs. W. Sissons and P. P. White in 1872. The mounting shows the general arrangement of an engineering work in which a dam has been formed by sheet piling, and the foundations are being prepared by sinking other piles.

The machine consists of a trussed lower carriage travelling on temporary rails, and carrying above a pair of rails at right angles to the lower ones. On the upper rails is a square platform, which carries the framing of the machine together with the steam boiler and winding gear. The front of the framing has timber guides, in which is secured the long vertical guides that control and direct the falling weight, or monkey. At the front the timber framing is carried on hinges, and the back legs are adjustable by screws, so that the face of the guides can be set to any desired batter. By making the guides independent of the framing of the machine, the former can be lowered much below the rail level, so that foundation piles can be driven right home, as shown in the model between the two rows of sheet piling. The base of the frame is square and its carrying wheels are castors, so that the machine will travel equally well when turned through 90 deg. The monkey is lifted by a continuously running endless pitch chain, passing round a sprocket wheel on the winch barrel. This chain goes over a pulley at the top of the guides and round a similar pulley at the bottom, thence over a guide wheel back to the winch. Through the monkey passes a bolt, which, by a pinion and external lever can be forced between the links of the pitch chain, so connecting the weight to the moving chain. When the desired height of drop has been reached, the bolt is withdrawn by a stop fixed to the guides, or it may be released by a hand rope, so allowing the monkey to fall. It is again raised by a pull at the hand rope, this causing the bolt to engage with the lifting chain. The long sliding guides, when raised to the correct position by the winch, are supported by the side chains at the front of the framing.

The boiler is of the vertical type, and supplies steam to a vertical double-acting engine. On the crank-shaft is a small smooth pulley which by friction drives a larger pulley on the intermediate shaft. One bearing of this shaft is carried in slides, so that by a hand lever the desired closing pressure can be obtained, or the friction wheel may be forced in the opposite direction

against the stationary brake-block when engaged in lowering. The intermediate shaft, by a pinion, drives a large spur wheel keyed to the long barrel shaft, on which are two drums and the sprocket wheel for the chain, and these can be thrown in or out of gear by claw couplings. The two winding drums are of use in lifting the long guides, and also when getting the pile into position for sinking. On the platform is also a feed tank, from which the boiler is supplied by a pump driven from the crank-shaft,

1569. Model of portable forge. (Scale 1 : 4.) Received 1906. M. 3450.

This apparatus, patented in 1879 by Dr. J. Hardinge, was designed to meet the wants of workmen engaged in outdoor repairs, and thus to avoid the delay involved in taking the work to a shop.

The hearth of the forge is supported on a metal frame, and upon the back of the standard is bolted the fan-case, which contains bearings for the fan shaft. This shaft also carries an emery wheel, a chuck for drilling, and a friction wheel by which it is driven. Attached to the frame is a shaft carrying the heavy driving wheel, and a pinion and ratchet wheel formed in one piece. On the hub of the driving wheel are one or more pawls gearing with the ratchet wheel. The pinion is driven by a toothed quadrant, which may be operated either by a treadle or a handle. A spiral spring acts as a counterbalance to the treadle. Attached to the frame is a vice and an anvil. Portions of the frame of the hearth can be removed to allow long rods to be laid in the fire.

1570. Model of helve or tilt hammer (working). (Scale 1 : 12.) Received 1842. M. 2694.

This represents a tilt hammer intended for use as a mining stamp, but with an alteration to the anvil top it resembles a type of hammer formerly used for tilting steel bars.

In the arrangement shown, an extension of the hammer shaft is lifted by a rotating four-arm cam. To increase the energy of the blow a spring beam is added; this also, by giving additional downward velocity, renders it possible for the hammer to strike at a higher speed than if it fell by gravity alone.

1571. Model of steam hammer (working). (Scale 1 : 4.) Presented by James Nasmyth, Esq, 1857. Plate IX., No. 4. M. 24.

This is a model of the original steam hammer invented by James Nasmyth about 1839 and patented in 1842. It consists of a base plate with a large central opening through which projects the top of the anvil, so that a blow on the anvil is not transmitted to the base plate. On the plate are secured two standards which form guides for the hammer-head or tup, and also support an overhead cylinder, the piston of which is connected with the tup by a piston rod passing through the bottom of the cylinder. Steam is admitted to this cylinder by a stop valve in the form of a slide, and then by a slide valve on the front of the cylinder, which by a hand lever can be moved so as to let steam in below the piston and so raise the heavy tup. When it is lifted to a height proportionate to the energy of the blow required, the steam is by the slide valve permitted to escape and the hammer falls upon the forging placed on the anvil. The cylinder is therefore only single-acting, but the top is closed, and a ring of holes communicating with the exhaust pipe is provided at a little distance down inside. In this way an air cushion is formed which helps to start the piston downwards when a long stroke is being taken, and also the steam below the piston is permitted to escape when the tup has been lifted as high as it can safely go. Soon after its invention the steam hammer was greatly increased in power by accelerating the fall of the tup by admitting steam above the piston in the downstroke and so changing it into the usual double-acting steam hammer.

The valve gear for regulating the number and strength of the blows is also arranged for working automatically. The slide valve of the hammer is connected with a small overhead steam cylinder which always acts in such a way as to let steam below the hammer piston and so keep the tup up, but a tappet on the tup when a certain height has been reached strikes a lever which reverses the slide valve and so lets the hammer fall. This reversing lever is carried on an adjustable fulcrum so that the reversal can take place at any desired lift of the tup. After reversal a catch retains the valve in this position, but when the blow is struck a swinging arm on the face of the tup by its momentum strikes an arrangement of levers by which this catch is released, and the valve allowed to return to the position required for commencing the next lift of the hammer. In this way the whole energy of the fall is utilised before the steam is permitted to act again on the upward stroke, irrespective of the thickness of the forging under treatment.

A copy of the original sketch by James Nasmyth of his first conceptions of the steam hammer is also exhibited, together with a small oil painting by him which shows the general arrangement of a heavy forge and the way in which a forging is manipulated while under the steam hammer.

1572. Model of steam hammer. (Scale 1 : 16.) Made from drawings supplied by Messrs. R. G. Ross & Son, 1905. M. 2256.

This is a double-acting hammer of the arrangement patented in 1854 by Mr. William Rigby. The cylinder is bolted to a single standard, thus leaving room for work on three sides. The piston and rod are in one forging and the latter has flats on two sides and a dovetailed end for the attachment of the hammer face. The gland and stuffing box are in halves and the former is of such depth as to render external guides unnecessary. The anvil block is dovetailed, like the hammer face, thus readily allowing changes to be made.

The admission of steam is controlled by a hand-worked piston valve; in addition the upstroke of the piston is automatically controlled by a tappet lever connected with the valve spindle and struck by the hammer head.

The anvil block is a separate solid casting which stands up through a hole in the sole plate; it has a broad base resting on a foundation of 15 in. sq. timbers. The sole plate is supported separately on similar timbers with the object of lessening vibration.

The piston rod and hammer face weigh 40 cwt.; the steam pressure used is about 30 lbs. per sq. in.

1573. Diagram model of Joy's steam hammer. (Scale 1 : 6.) Presented by D. Joy, Esq., 1900. M. 3098.

This represents a double-acting hammer, patented by Mr. Joy in 1860, in which the motion of the reversing valve, hitherto performed by levers or tappets, is directly obtained by steam pressure. This is accomplished by causing the piston, when near either end of its stroke, to uncover a port or hole in the side of the cylinder, and thus allow steam from the cylinder to pass directly to the end of the valve, which is of the piston type, and thus push it into the reverse position. The valve is, moreover, made hollow, and allows the steam, after it has acted on the lower side of the piston and lifted the hammer, to pass through to the upper side to assist the downstroke, thus using the steam expansively, as in a compound engine. To regulate the stroke of the hammer there are holes or ports at various heights up the cylinder, opening into a channel in which slides a plug worked by a hand lever, so that the holes may be opened or closed, and thus an early or late admission of steam to the valve which reverses the stroke be obtained. A stopcock is provided to diminish, or close entirely, the port at the upper end of the cylinder, thus reducing the opening of the valve and thereby moderating the force of the blow.

1574. Model of steam hammer (working.) (Scale 1 : 12.) Received 1906. M. 3463.

This represents a double-acting steam hammer with self-acting gear, made by Messrs. Davy Brothers. The cylinder is mounted on a double frame of the ordinary Nasmyth pattern and the hammer head slides between guides formed on it. Steam is admitted through a sliding regulator valve, and distributed by a piston valve having a third central piston which divides the steam chest into two parts, each with a separate steam inlet controlled by the regulator so that steam may be admitted to the underside of the piston only. The self-acting mechanism consists of a bell-crank lever, one arm of which is fitted with a swivel block working in an inclined slot formed in the face of the tup, while the other arm is connected with the piston valve spindle. The bell-crank lever is pivoted on a movable fulcrum, the raising or lowering of which varies the stroke. The hammer frame is bolted to a base plate resting on concrete piers and having a central opening through which the top of the anvil projects. The anvil block rests on a separate foundation of timber balks, bolted together, with a bed of concrete beneath it. The cylinder is 12 in. diam., and the weight of hammer head, piston, and rod is about 16 cwt.

1575. Model of steam hammer (working). (Scale 1 : 12.) Lent by Messrs. B. & S. Massey, 1892. M. 2415.

This model shows a form of double-acting steam hammer, intended for general smith-work. By the use of an overhanging framing the hammer is rendered accessible for work on three sides, but for the heavier types this form of framing is not adopted.

The cast-iron side frames carry the steam cylinder, and form also the guides for the hammer head, which may be of forged iron or steel. The base plate carries the frames, and through a bored hole in it passes the turned circular anvil block, which transmits the unabsorbed portion of the blow to the foundations shown below. The equilibrium working valve is of the piston type, with the steam in the middle and the exhaust at each end. A lever for working the valve by hand is carried backwards between the frames, and a swinging lever, actuated by the tup and carried on an adjustable fulcrum for varying the stroke, is arranged to move the valve automatically when rapid or regular blows are desired. Owing to the heavy shocks, the piston is forged solid with the rod, but the hammer and anvil faces are removable.

The adjacent photographs show a 15-cwt. Rigby steam hammer for heavy smith-work, and a 30-cwt. arch-frame hammer; in both cases the automatic valve gear, by which the head is prevented from being lifted too high, is clearly visible.

1576. Model of power hammer (working). (Scale 1 : 8.) Presented by Messrs. Peter Pilkington, Ltd., 1904. M. 3336.

In this mechanically driven hammer, the hammer-head is directly worked by an air-cylinder, in which the pressure is being successively diminished and augmented, owing to its being in communication with another cylinder in which a piston is reciprocated by the motive power. By this system of working, which was first patented in 1860 by Mr. T. G. Dawes and has since been developed by others, an elastic, rapid and adjustable blow is obtained with a self-contained machine.

The modern arrangement shown was patented in 1894 by Mr. R. M. Reay. The hammer-head is directly connected with a plunger which serves as a single-acting piston and also as its guide, while the upper end of the cylinder in which it works is in communication with another cylinder combined with the main standards and having in it a single-acting trunk piston actuated by a balanced crank on a flywheel shaft, driven by belting from line shafting or an electric motor. The hammer is stopped or its blow varied by two rotary non-return slide valves in the passage connecting the two cylinders. One

valve, actuated by a hand lever, controls the passage from the air cylinder to the valve chamber; the other, which is connected with a treadle, controls the passage from the valve chamber to the hammer cylinder; at the top of the stroke the hammer piston passes over the port of this passage, so as to ensure pneumatic cushioning. When the passage is free, the motion of the hammer follows that of the air piston; the force of the blow can, however, be lessened by slightly covering the port to the hammer cylinder. If the latter be completely covered the hammer will be lifted to the top of its stroke and will remain there. If it be desired to retain the hammer in an intermediate position the ports to both cylinders must be covered when that position is reached, but if it is required to use the hammer as a vice, the port to the air cylinder must be covered and the port to the hammer cylinder uncovered. The air cylinder is provided with a safety non-return valve.

These hammers are built in sizes from 1·5 to 10 cwt., that represented being of the smallest size, which has a stroke of 8 in. and can deal with a maximum thickness of 2 in.; it gives 220 blows per min. and requires 3 H.P.

1577. Portable pneumatic hammer. Lent by the International Pneumatic Tool Co., 1901. M. 3208.

Portable hammers, driven by compressed air and sometimes by steam, have been occasionally used in England since 1860, but their recent extensive adoption is due to the success with which the invention has been revived and commercially introduced in America. The principle of their action is that a free and comparatively heavy piston is reciprocated in a cylinder by air pressure, and strikes the head of a chisel, or similar tool, inserted into one end of the cylinder. The greater inertia of the cylinder causes its movement, under the rapid reversals, to be so much less than that of the internal hammering piston as to be quite endurable. There are two types of these portable hammers: the valveless, in which the piston itself distributes the air and gives from 10,000 to 15,000 short-stroke light blows per min.; and the valve hammer, which, with a separate distributing valve and a longer piston stroke, gives from 1,000 to 3,000 heavier blows per min. The air pressure now used is generally from 70 to 100 lbs. per sq. in., and it is stated that for general work a man with one of these hammers performs the work of two men with hand tools, while at caulking he is equal to three men.

The hammer shown by this sectioned example was patented in this country in 1899 by Mr. H. J. Kimmans, of Chicago, and is of the valve type. It is made entirely of steel, and is provided with a hollow handle through which compressed air from a flexible pipe is introduced; the supply is turned on by a throttle valve, controlled by the thumb of the operator and provided with a milled head by which the amount of its opening can be adjusted. The distributing valve, which causes the rapid reversals of the motion of the hammer piston, is of the piston type with an enlarged head, and is moved entirely by the air acting on this head. When the hammer piston is at the back of the cylinder, the valve is pushed outwards and so allows air to pass directly behind it into the cylinder, so that the piston is driven forwards till it strikes the chisel. In this position a groove round the piston places a port leading to the valve head in communication with pressure air, so that the valve moves and causes air to enter the front of the cylinder, the return stroke then taking place, at the end of which the hammer piston is ultimately stopped by an air cushion formed by its closing its exhaust port.

This size of hammer has a cylinder 1·125 in. diam. and a stroke of 3 in.; the piston weighs ·87 lbs. and the whole appliance 9·5 lbs. The normal speed is 2,000 blows per min. and the consumption 15 cub. ft. of free air in the same interval.

1578. Model of rotary squeezer for puddled balls. (Scale 1 : 12.) Presented by G. B. Thorneycroft, Esq., 1861. M. 607.

This is a machine patented by Mr. Thorneycroft in 1843 to operate upon puddled balls in the manufacture of wrought iron, in place of the "crocodile squeezer," or the rotary machine of Brown. A large serrated roller revolves

within a serrated semi-circular race or breast, in which it is eccentrically placed. The puddled ball from the puddling furnace is inserted at the widest place, viz., at the commencement of the race, and is rolled over and over between the serrated roller and the serrated casing on its way from the wide to the narrow end of the race, from which it emerges in the form of a bloom ready for the rolling mill, having had most of its cinder expressed from it in the process.

1579. Model of forge train for merchant bars. (Scale 1 : 16.) M. 2710.

The model shows two pairs of rolls mounted in the usual housings, and carried in bearing chocks which when removed permit of the withdrawal of the rolls. The rolls are grooved for the production of merchant bars after the iron has been drawn down under the forge rolls.

1580. Model of forging machine. (Scale 1 : 4.) Contributed by W. Ryder, Esq., 1857. Plate IX., No. 7. M. 27.

This is a machine patented by Mr. W. Ryder in 1841, for forging bars of iron and steel while red-hot.

A number of dies or swages of any desired form are fixed in the machine in pairs, the lower dies being fixed in the framing, with screw adjustments, while the upper ones are moved very rapidly up and down by means of eccentrics on the upper shaft, which is driven at about 600 revs. per min. The pairs of dies are generally arranged in a series of varying diameters. One of the lower dies is moved up and down in concert with the upper die, by means of a cam on a short shaft below; these two tools form cutting dies or shears. Such machines forge suitable objects with great rapidity and of almost standard diminsions; some examples of such forgings are shown.

1581. Pneumatic riveter. Lent by Messrs. De Bergue & Co., 1887. M. 1874.

This is a portable riveting machine, patented by Mr. J. F. Allan in 1879, for working by compressed air.

A piston, provided with a hollow piston rod or trunk, works in a cylinder, having a slide valve worked by a hand lever. A connecting rod from the piston gives motion to the movable die through the medium of a species of toggle-joint, by which an increasing power is obtained so that the pressure upon the rivet is gradually increased, and the consumption of air in the preliminary closing is reduced; the trunk piston is returned by a little air let into the small annular chamber it leaves. The machine can be slung and moved about by a crane, or other convenient means, the compressed air being conveyed to it through a flexible pipe, as in the case of hydraulic riveters.

1582. Model of hydraulic forging press. (Scale 1 : 8.) Lent by R. H. Tweddell, Esq., 1895. M. 2747.

Instead of forging by blows, it is now becoming increasingly general to work the heated metal by steady pressure. The pressure method is slower, but, where the mass of the forging is large, the unequal distribution through the work of the blow from a hammer is considered by many to produce flaws that are avoided by the uniform flow resulting from sustained pressure. Machine riveting is an application of forging by pressure, but when the size of a rivet is compared with that of a moderate forging, the extension of the system to general work is seen to involve pressures that hydraulic power can alone supply.

The model shows a complete forging press of the form patented by Messrs. R. H. Tweddell, J. Fielding, and J. Platt in 1885. The lower block, which occupies the position of an anvil, is secured to side standards

built in masonry, and is stationary. The upper block, which represents the tup of a hammer, is formed as a crosshead, from which descend, through guides, two tie-bars to a similar crosshead below the anvil. A small hydraulic ram below the lower crosshead tends always to lift it, so that the tup is normally up. Three rams, acting downwards from the anvil to the lower crosshead, press the tup down when the pressure water is admitted into them; by this arrangement the forging pressure of one, two, or three rams can be exerted as required, and so pressure water be saved when on light work.

To the anvil and tup different swage blocks are cottered as shown, according to the work in hand; those now in position being suited for drawing down a round shaft.

1583. Model of chain-pressing machine. (Scale 1 : 8.) Lent by Weldless Chains, Ltd., 1907. M. 3523.

Many attempts have been made to produce chains of the ordinary type which should be without weakness due to the welds, and such chains have been manufactured by cold punching from a cruciform bar, but their size was limited and the cost high. Weldless chains are now, however, being successfully made by impressing the link form upon red-hot steel bars of cruciform section, and the model represents a machine for this purpose, patented by Mr. A. G. Strathern in 1897–1904.

The machine consists of a heavy framework having four horizontal crank-shafts, one at each corner, geared together and driven by an engine. Each crank actuates a slide working in diagonal guides cast on the frame, and the slides carry at their inner ends pivoted quadrants, to which the pressing dies are attached. The dies are formed as segments of a circle with a double-bevelled edge, upon which the link forms are cut, and they each enter one of the angles of the cruciform bar. The die faces are mounted eccentrically with the pivots, so that the inward pressure causes them to rotate and press and feed forward the bar at the same time. The rolling motion of the dies is controlled by links, connected with a cam gear, which prevents the lateral movement being too rapid, and so releasing the pressure on the bar, and ensures that such motion shall only commence when the forward edges of the dies have advanced right to the centre. When the dies have completed a stroke they are withdrawn, and returned to their original position, the bar remaining stationary until they are again fed forward. The front ends of the dies are arranged to register with, and so prevent deformation of, the links already formed. The actual machine is provided with a means of adjusting the dies, and a water service is arranged to cool them after each revolution. The machine is placed close to the front of a furnace 40 ft. in length, and the bars travel through at a speed of 20 ft. per min., being sufficiently heated during their passage.

On leaving the pressing machine the chain is held rigid by thin webs of metal surrounding the links, and, when cool, is passed through other machines which remove the webs, separate the links, and finish them to the correct size and shape. The links are made with thickened ends, and the machine produces chains from ·25 in. to ·625 in. diam., and from 60 ft. to 90 ft. in length. Tests have shown that a weldless steel chain is twice as strong as an ordinary welded iron chain of the same size.

1584. Model of machine for rolling disc wheels. (Scale 1 : 12.) Presented by the Institution of Civil Engineers, 1868. M. 1071.

This is a form of rolling mill for making solid disc railway wheels. A pair of conical rollers, mounted on two inclined shafts driven by bevel gearing, are forced against the disc by right and left-hand screws, and cause it to revolve on its axis. The pressure so rolls out the red-hot metal as to leave it as a wheel with a thick boss and tire. Steadying rollers are provided to keep the disc true while being rolled.

1585. Model of tire-bender. (Scale 1 : 4.) Lent by Messrs. F. & T. Affleck, 1891. M. 2383.

This is a machine for bending a bar of iron into the form of a hoop, or for trueing up the hoop or tire after the ends have been welded together. It has three horizontal rolls, the middle one, which is driven by a four-armed handle, driving one of the side rolls by spur gear. The other side roll is carried in sliding bearings which can, by two screws, be adjusted to give the desired curvature to the bar to be bent, which passes under the central roll and over the two outer ones. To enable a welded tire to be rolled, the central roll is capable of being quickly withdrawn through its front bearing, so that the ring can be placed in position. A simple form of tire-drilling machine, with an adjustable rest, is combined with the bender.

1586. Model of tire-rolling mill. (Scale 1 : 6.) Lent by William Melling, Esq., 1904. M. 3370.

Tires for the wheels of rolling stock were originally made in the same way as those for cart wheels, *i.e.*, by bending a bar, of the correct section and length, by means of three rolls and then welding it. About 1845 it had become the practice to apply powerful machinery to reducing the tire to exact section and circularity by rolling after welding. This is the method shown by the model which represents an improved machine constructed about 1850 by Mr. Melling, of Haigh Foundry. There are two rolls, of the internal and external profile of the tire respectively, arranged vertically on a horizontal table provided with slots; the inner roll is connected by bevel gearing with a source of power and is spur-geared with the outer roll, thus only permitting screw adjustment within very narrow limits; different thicknesses of tire would be accommodated by changing the rolls. To the outer roll are geared two other rolls to give the required bending to the tire. These also have screw adjustment, and to admit of the necessary latitude for different diameters, and to drive in the right direction, an idle wheel kept in gear by links is provided. To keep down the tire on the table, a loose roller, which can be fixed in different positions on a hinged lever, is provided. To the table are bolted loose guide rolls which the tire touches when the correct diameter is attained; these are set by a trammel (not shown) centred on a pin in the middle of the table.

A modified machine is used for making weldless tires, which have become universal since the introduction of mild steel, which is suitable for this treatment.

1587. Model of spoke-bender. (Scale 1 : 6.) Lent by William Melling, Esq., 1904. M. 3371.

The sector-spoked wrought-iron wheel was patented by Mr. W. Losh in 1830, before which cast-iron centres were generally used. Losh's wheels were almost exclusively used for the rolling stock of the early railways, and are still retained for wagon wheels.

The machine shown, which was introduced about 1850 by Mr. Melling, of Haigh Foundry, is for economically bending such spokes. Bars rolled or drawn down by forging so as to leave greater thickness in the middle are bent roughly to shape whilst hot and clamped on a die block secured to the crosshead of a hydraulic ram; as the ram ascends, links pinned to it and hinged to links fixed on the framing close against the sides forming the completed outline. The wheel centre is completed by riveting or welding the adjacent spokes together, casting the nave round the inner ends in a suitable moulding box, and turning up the circumference.

1588. Model of rolls for marking rods. (Scale 1 : 6.) Presented by the Lords of the Admiralty, 1864. M. 2727.

This model represents a machine introduced by Sir R. Seppings in 1829 for rolling and branding the metal rods required for making ships' bolts. It

consists of two equal rolls mounted in wood and iron housings, and worked by a winch handle apiece; screws are provided to regulate the distance between the rolls. There are three round passes, but the middle one is slightly corrugated, and on the top of each ridge bears the broad arrow, the impression of which is left on the metal every few inches in the length of the rods.

1589. Wire-straightening machine. Received 1908. M. 3551.

This is a small appliance for straightening wire. It consists of a cast-iron base plate having mounted upon it five grooved pulleys or rollers, placed alternately on each side of the wire, which is drawn between them, the smaller sizes by hand and the larger sizes by a draw bench. The end rollers are fixed in position while the intermediate ones are mounted on blocks, clamped by bolts whose heads move in transverse slots, thus giving the necessary lateral adjustment. A guide is fitted to lead the wire from the coil to the first roller. The machine straightens wire from ·08 to ·25 in. diam.

1590. Electric welding machine. Made by the Electric Welding Co., Ltd., 1904. M. 3360.

This is a small machine for welding wire by the process introduced by Prof. Elihu Thomson in 1886, in which the heating is performed by a powerful current of electricity sent through the proposed joint, while, at the same time, the parts are pressed together mechanically.

The pieces to be welded are prepared by having their ends made slightly convex and are then firmly held in clamps, one of which is fixed whilst the other is carried on a slide and is urged towards the fixed one by an adjustable spring provided with a controlling handle and a locking arrangement. The clamps are insulated and form the terminals of the secondary coil of a specially designed step-down transformer arranged in the base of the machine, by which an alternating current of convenient potential is converted into a low-pressure current sufficient to overcome the low resistance of the welding circuit, but of the greater volume necessary to ensure rapid heating; by this arrangement the difficulties that would be experienced in generating and distributing a current of the volume required for larger welds are entirely avoided. The low resistance of this welding circuit causes the heating to be confined almost entirely to the junction, at first through the imperfect contact and afterwards through the higher resistance of the hot metal; the convexity of the ends, moreover, causes the welding to commence at the interior, so that any scale is expelled and a good joint is obtained throughout. The controlling handle, which regulates the approach of the terminal clamps, has an adjustable sector connected with an arm operating a switch in the primary circuit of the transformer, and is so arranged that when the clamps have approached each other sufficiently, through the upsetting of the metal, to ensure a good joint, the circuit is automatically broken. Gauges are, moreover, provided to facilitate the setting of the metal in the clamps, the amount of projection from which varies with the size of the work. The secondary or welding circuit of the transformer is in the form of a single massive copper loop and partly surrounds the primary coil, which consists of many turns of copper wire; a laminated iron core, giving a closed magnetic circuit, is combined with the transformer.

Welding machines of this construction of considerable capacity are in use, but this small example, which is known as an automatic wire-welder and is only intended for small work, is suitable for dealing with iron wire from Nos. 18 to 6 I.W.G., or copper wire from 18 to 11 I.W.G.; the adjacent specimens show work done by it and the swelled form of joint produced.

1591. Model of coining press. (Scale 1 : 8.) Maudslay Collection, 1900. M. 3124.

This represents a cutting-out press for coin blanks, and was made about 1814. The bolster is mounted on the head of a cast-iron frame and the die is carried in a massive crosshead, with adjusting nuts, reciprocated by an

eccentric on a driving shaft below. The strip of coin metal is fed in by rolls, geared together and intermittently turned by a ratchet driven by a pin on the driving shaft.

1592. Model of shearing machine. (Scale 1 : 12.) Presented by G. B. Thorneycroft, Esq., 1861. M. 682.

This represents a machine patented in 1843 by Mr. Thorneycroft for shearing large iron plates. The lower blade is fixed and the upper one slides in guides formed in side standards, which hold the bearings of a strong horizontal shaft; three cams on this shaft force the blade downwards, and two light eccentrics lift it for the next stroke. The shaft has square ends, and was probably to have been driven by a cast-iron breaking shaft that would fail if the cut attempted was too heavy. The cutting edge of the moving blade is inclined, so that the cut is taken gradually across the plate and the work distributed throughout the stroke, the maximum pressure being thereby greatly reduced.

1593. Model of punching and shearing machine. (Scale 1 : 8.) Lent by Messrs. Craig & Donald, Ltd., 1906. M. 3444.

These two machine tools are, as is usual, combined in one framing for convenience in working, to save floor space, and because of the similarity of the operations performed.

The machine is of the eccentric type; it has a massive cast-iron framing with a deep gap at each end to enable the plate to be punched or sheared at a distance from its edge. Overhanging both gaps is a main shaft of large diameter, the speed of which is reduced by spur gearing in the ratio 1 : 10·5 from that of the first motion shaft, which carries fast and loose pulleys and a flywheel for overcoming the variable resistance. Each end of the main shaft is turned down eccentrically and on the pin thus formed is fitted a block which slides in a horizontal slot in an apron situated between adjustable V guides; a reciprocating movement is thus impressed on the apron. To its lower face is bolted the shear blade or punch. For punching there is a stop motion, consisting of a cam interposed between the block and the apron, which can be turned by a handle. This allows of the exact adjustment of the plate under the punch, the latter coming down to the surface without being forced through. This mechanism is not required in the case of shears. An adjustable hinged forked piece between the punch and its bolster serves to strip the plate off the punch as it rises.

The punch and shears move continuously, but their working periods alternate, so as to lessen the fluctuation in energy absorbed. Simple radial post cranes. each with a trolley for conveniently slinging the heavier pieces, are incorporated with the framing.

1594. Model of punching, shearing, and notching machine. (Scale 1 : 8.) Lent by Messrs. Craig & Donald, Ltd. Plate X., No. 1. M. 3445.

This resembles the preceding (No. 1593) except that a third machine tool is combined in the one framing and that the construction is of the lever type. The main shaft, whose speed is reduced by spur gearing as before, is placed at right angles to the position adopted in the eccentric type. On the main shaft are two cams for each lever which rub on a beam suspended from the end of the lever by tie-rods. One end of the lever is centred in the framing and, for punching, the other end presses on a D-shaped punch-block, which slides in a vertical sleeve and is raised by two side levers slotted to allow the stop motion to operate; this consists of a cam interposed between the lever and the punch-block and turned down by a handle. For shearing, the outer end of the lever is inserted in the apron carrying the shear blade. A connecting block is hung in a space within the apron from an eccentric pin on the end of the shaft. The pressure is thus always exerted centrally. Another block inserted between the former one and the apron provides for

the stop motion. The two blocks are slotted and can be moved back by a handle so that one enters the other to the amount of the stroke. The punch and shears have each a period of rest determined by the cams, which are so timed that their periods of operation and that of the notcher are consecutive. Jib cranes are incorporated with the framing.

1595. Expanded metal. Presented by the New Expanded Metal Co., Ltd., 1892 and 1902. M. 2430.

The process and machinery for converting a sheet of metal into a trellis or network by shearing it through at intervals, and at the same time bending or stretching the partly-severed strips, was patented in 1884 by Mr. J. F, Golding, of Chicago, and subsequently improved. The work is completely performed, without the removal of any portion of the original plate, in a long shearing machine provided with suitably shaped blades, and fitted with mechanism for holding and feeding the plate.

In the original type of machine the upper and lower blades were formed of small elements, each set back from its neighbour to the left, while the sheet or strip of metal to be operated upon was fed in diagonally from one side of the stepped jaw. A photograph shows this machine, and there are three specimens relating to the trellis made by it; first the sheet of metal, then the sheet with one-half converted into trellis, and finally the piece completed. From these it will be seen that the whole diagonal line of cuts is made with one stroke of the shears, which, at the same time, bend down the strips without stretching the metal. In this way sheets of mild steel of 16 to 20 I.W.G., 9 ft. long by 7 in. wide, were converted into pieces of trellis 8 ft. long by 5 ft. wide, the reduction in length being due to the diagonal arrangement of the material after being expanded without being stretched.

In the later machine, shown in another photograph, and whose work is illustrated by a piece of ·19-in. thick steel plate, one-half of which it has converted into trellis of 3-in. mesh and ·375-in. strand, the lower shearing blade is straight, while the upper one is of notched outline. The sheets are fed through from the back at right angles to the blades, and the notched blade, as it descends, at first cuts a series of slits in a straight line along the edge of the plate, and then stretches the severed strands while depressing them into the mesh outline, so that the length of the sheet remains unaltered. Between each stroke the plate is moved laterally through a distance equal to half of the pitch of the corrugations, so that the slits in one row come opposite the bars in the next, and the trellis is formed with lozenge-shaped spaces. The sheets converted in this machine range from No. 24 to No. 3 I.W.G. and are 8 ft. in length, but after extension their width is from twice to twelve times what it was originally.

Owing to the stiffness and good bonding surfaces that this trellis possesses, the lighter gauges are largely used as lathing for ceilings or plaster partition walls, while the heavier kinds are employed to reinforce concrete floors and other structures by introducing steel into those portions of the concrete under tension.

1596. Pole lathe. Lent by Messrs. Thos. Noakes & Sons, Ltd., 1907. M. 3514.

The earliest known form of the lathe was very simple. It consisted of two fixed centres between which the work was supported, and motion was given to the work by a bow, the string of which was wrapped round it, or by a cord the ends of which were pulled by an assistant. The turner was seated upon the ground holding the tool against a rest with one hand and working the bow with the other, cutting being performed during one half of the motion when the work was revolving towards him. Such lathes are still used in the East. In Europe, however, probably owing to the erect position generally adopted by the turner, the fixed centres were placed higher and an improved method of rotating the work was employed. In this the bow was replaced by a spring beam or pole above the lathe, and a cord was fastened

to the free end of it, then wrapped round the work and its lower end attached to a treadle to be worked by the foot. This method largely increased the power and left both hands free for the management of the tool. The pole lathe shown was made about 1800 and was in use by Messrs. Noakes occasionally as late as 1879 for turning such objects as the beer cock shown. Similar lathes are still used by the chairmakers of High Wycombe and Oxfordshire. The lathe bed consists of two oaken beams a few inches apart, mounted on two posts which are provided with feet for attachment to the floor. The headstocks are massive blocks of oak passing between the beams and each carrying a fixed iron centre; one head is fast and secured by a wedge, while the other is loose and may be secured by a clamping bolt in any position along the bed. The cocks to be turned are mounted on a wooden mandrel, and a wooden tool rest, shaped to suit them, is secured to the bed by a clamp. The pole consists of a straight tapered bough of a tree, and in practice it would be held at one end and supported on a cross bar at about the middle of its length in order to provide for lateral adjustment. The driving cord is attached to the free end of the pole, passes round the mandrel, and then between the bed to the treadle below which consists of two pieces of wood attached to the floor by leather hinges. A back rail is fitted to the lathe for the support of the operator.

1597. Rose engine. Received 1872. Plate X., No. 2. M. 1912.

This is the bench portion of a German lathe made about 1750 for ornamental turning, but the general arrangement of the complete machine is shown in the adjacent photograph. The lathe was driven from a pulley on an overhead shaft carrying a flywheel, which received its motion from a cord connected to a treadle in the base. This shaft was supported in an adjustable bearing box, carried by a framework secured to a massive wooden cabinet with which the lathe was combined, but the whole machine was covered with a mass of rococo decoration by which the framework was concealed.

The mandrel headstock is hinged below and provided with a strong spring to keep any one of the several cams or rosettes, which the mandrel carries, in close contact with a fixed rubber. The rocking or "chattering" motion thus imparted to the mandrel as it revolves causes a stationary cutting tool to produce on the work a wavy line or rosette instead of a true circle.

The pattern shown on the boxwood in the chuck is one generally employed for the backs of watch cases, and is produced by using a cam with 24 similar waves; by means of a tangent-screw the cam is rotated, relatively to the work, through half a wave between consecutive cuts, and this causes the depressions of one ring on the work to correspond with the tops of the waves of its adjacent ring, and produces the appearance of spiral curves, although the design is built up entirely of concentric rings. As several different cams are provided, many designs may be obtained by suitably manipulating the tangent-screw.

Another set of cams is arranged to give end motions to the mandrel, so that a cylindrical surface can be ornamented, or lines may be cut of varying thicknesses on face work. The headstock can, moreover, be clamped by screws, and the lathe be thus rendered suitable for ordinary turning.

The rose engine is still used for certain decorations, but in the modern machine, some specimens of work from which are shown, the cam is relatively very much larger than in this early example.

1598. Bar lathe. Presented by Bryan Donkin, Esq., jun. 1890. M. 2286.

This lathe was made and used by the late Bryan Donkin, F.R.S. The bed is a finished triangular bar which was the usual form for small lathes before planing machines were introduced. The face of the cone pulley is drilled for use as a dividing plate; the corresponding locking pin is attached to the headstock.

1599. Watchmakers' lathe. Contributed by R. Bodmer, Esq., 1857. M. 55.

The mandrel of this lathe carries at one end a chuck or face-plate with three dogs or clamps for holding the work, and at the other end a pinion with diagonal teeth gearing into a wheel fixed on an axis parallel to the mandrel, and provided with a handle by which the mandrel is caused to rotate. The mandrel is hollow, and is fitted with a cylindrical spindle having a conical point to centre the work by. A slide-rest is provided in front of the face-plate for operating on the work.

1600. Machine for originating screws. Maudslay Collection, 1900. M. 3119.

This appliance was made by Henry Maudslay about the year 1800, for the purpose of producing screw threads of any desired pitch. He had tried to obtain an accurate thread by winding steel tape round a cylindrical bar and by other means; but the method introduced in this machine consists in the use of a chisel edge, secured at the calculated angle with the axis of the bar to be screwed and free to travel, without turning, along the revolving bar under the action of the inclined edge. Cylinders of hard wood and soft metal were employed, and from the best of the screws thus obtained copies were produced in steel for use as standard screws, which were subsequently still further improved by various methods.

The instrument consists of a flat horizontal plate beneath which projects a lug pierced by a cylindrical horizontal hole 1·5 in. diam. through which is passed the bar to be screwed; the bar is then placed in a lathe, the bed of which prevents the rotation of the plate while permitting it to slide longitudinally. Through the top of the whole projects downwards a concave chisel edge, carried by a holder secured to a large disc provided with a tangent screw adjustment finely graduated, so that the chisel edge can be set at the exact inclination with the axis of the cylinder corresponding with the pitch of the thread desired. Through the side of the hole enters the front of a chaser of the same pitch, carried in a small slide-rest with screw adjustment, while the chisel edge is forced downwards into the work by a screw fixed above the graduated circle. When the cylindrical rod is rotated the inclined action of the chisel causes this screwing stock to travel along the bar, and the chaser which follows cuts the thread thus started.

1601. Screw-cutting lathe. Maudslay Collection, 1900. Plate X., No. 7. M. 3117.

This lathe was constructed at the end of the 18th century, and is believed to be the first workshop machine in which Henry Maudslay combined a leading screw and change wheels for producing screw threads.

The bed consists of two triangular bars, secured at a fixed distance apart and supported on feet by which it was secured to a bench; the height of the centres is 1·5 in. and the length of the bed about 3 ft. The head-stocks are fixed to the back bar only, but the slide rest, which is of gunmetal, slides on both bars and carries a tool-holder which can be moved to or from the work in V slides by means of a screw fitted with a graduated disc and a winch handle. Between the two guide bars is a metal leading screw 1 in. diam, by ·25 in. pitch, cut with a square thread which is, however, exceptionally narrow. This leading screw was geared to the lathe spindle by change wheels, while a split nut and a clamping device at the bottom of the saddle formed a connection between the saddle and screw which could be released when desired.

1602. Maudslay's screw-cutting lathe. Maudslay Collection, 1900. M. 3116.

This is a small example of the original screw-cutting apparatus invented by Henry Maudslay about the year 1800, in which, by the combination of a mechanical tool-holder or slide-rest, with a power-driven screw feed, the screw-cutting lathe was produced.

The lathe is arranged for driving by hand power; the screw to be cut is carried between centres, while the leading screw is low down in the bed, and a wide saddle which carries the upper rest or tool-holder is connected to it by a form of split-nut, adjustable from below; the saddle also carries an adjustable stay to prevent springing of the rod being screwed, while the depth of the cut is controlled by a hand wheel with a graduated edge. The leading screw has 30 threads to the inch and on its axis is a wheel of 24 teeth which, through an intermediate wheel, gears with a wheel of 45 teeth on the lathe axis, so that the screw being cut has 16 threads to the inch. The lathe is provided with 28 change wheels with teeth varying in number from 15 to 50; the intermediate wheel has a wide face and is carried on a swinging adjustable arm so that it can connect wheels of various diameters at the fixed centres.

With the lathe is shown a collection of screwing tools, both with single cutting points and the various forms of multiple-point cutting tool or chaser. while samples of screws cut in a similar machine and having from 16 to 100 threads to the inch are shown. There are also two pairs of wide calipers used for measuring the diameter of a screwed surface, and these are provided with long ends which increase the reading in the ratio of 4 : 1.

1603. Lathe and appliances. Presented by Maj.-Gen. H. P. Babbage, 1906. M. 1461.

This lathe was formerly used by Charles Babbage, F.R.S., in his experimental work. It was so constructed that practically all machine shop operations could be done by its aid at a time when separate machine tools had not been developed.

The lathe bed is of cast iron and is fixed to wooden supports. The mandrel, whose height from the bed is 6·5 in., has a single pulley driven by a belt from a step pulley on a flywheel actuated by a treadle; the headstock is moved along the bed to bring the pulley in line with the desired step, and to allow of this the belt has a buckle connection. The pulley has a division plate of 200, 180, 112, and 12 holes, with a plain index. The compound slide-rest was made in 1823–4 by Joseph Clement, and was the second of its kind. It has three slides; the lowest, of shallow depth, can be clamped in any position transverse to the bed. To this is bolted a slide, with a leading screw of 9 V-threads to the inch, capable of rotary adjustment through about 45 deg.; the topmost slide is traversed by this screw and has alternative positions for the tool-holder. One holder is shown in an adjoining case while another on the slide-rest is fitted with a machine vice whose position can be adjusted vertically by a screw, and it is also capable of partial rotation, being divided on the edge for that purpose. To this vice can be clamped any piece of work to be machined by a milling cutter, boring-head, or bar, between centres or held in a chuck.

A slotted bracket, fixed in alternative positions on the lowest slide of the rest, is provided for attaching work which is to be shaped, planed, or slotted. To give the desired quick traverse to the tool slide, the rack shown in the case is attached at the inside.

When it is desired to use the lathe for screw-cutting, a chuck with one of the toothed wheels keyed on it is put on the mandrel. In gear with it is a train, according to the pitch desired, held on the quadrant bolted to the lathe bed, and ending in a wheel keyed on the end of the leading screw of the slide-rest.

The appliances, made between 1824 and 1830, include the change wheels used for screw-cutting and a number of face-plates and other chucks for wood and iron; among the latter is a two-jaw chuck, self-centring by means of a right and a left handed screw. The self-centring wire chuck was contrived by Mr. S. Mordan for use in making his pencil cases, patented in 1822, and is the precursor of many modern drill chucks. Two hardened steel jaws slide in a dovetailed diametrical groove. The outside edges are

turned conical and the jaws are forced together by a muff, with a corresponding interior, screwed over them. In the independent three-jaw chuck for small work, the jaws are each adjusted by a set screw. There is also a chuck for cutting discs or washers. The cutter is held by a set screw in a dovetailed slide which is adjustable diametrically The boss projecting in the centre is removable and acts as a guide by entering a hole already made. One of the later tools designed by Mr. Babbage is the adjustable face milling cutter. This is a face chuck provided on the circumference with grooves to hold eight steel cutters held by wedges which are tightened up by tail screws. The cutters were ground on one face and one end in a special holder; they were set for diameter by bottoming in their grooves and for projection by a distance piece. This tool was extensively used in facing and ending all kinds of rectilinear work fixed to the slide-rest.

The turning tools for wood are made of short pieces of steel which are held at the cutting angle in the cranked end of a holder by means of a strap, tightened by screwing up a wedge. For iron turning tools, similar cutters are held at angles of 45 deg. in a slotted bolt or in a saw-cut pinched by a screw. It is believed that Mr. Babbage was the inventor of this now common and convenient arrangement.

1604. Model of segmental lathe. (Scale 1 : 12.) Presented by Messrs. Bullivant & Co., 1891. M. 1654.

This represents a machine, probably constructed about 1830, for turning cylindrical portions of objects in which complete revolution was either unnecessary or impossible; such tools have been used for machining crank arms and valve gear links.

At the top of two tall standards, which are extensions of the fast headstock of a lathe, is a speed cone and flywheel, driving, by reducing gear, an overhanging crank arm of adjustable throw. A connecting rod from the crank works a rack sliding in vertical guides and gearing into a spur wheel secured to the headstock mandrel so that, as the crank rotates, the work in the lathe is rotated to and fro through an angle that is determined by the throw of the crank. The length of the connecting rod is also adjustable so that the portion of the work being operated upon can be quickly changed.

The lathe bed has an internal traversing screw, and carries a slide-rest, the tool-holder of which is of the hinged type necessary in planing machines.

1605. Engraving of self-acting lathe. Contributed by Messrs. Joseph Whitworth & Co., 1857. M. 103.

This shows the self-acting lathe patented by Sir Joseph Whitworth in 1835. The leading screw is placed within the bed and, in addition to its use in screw-cutting, serves as a rack when moving the saddle by hand and also gives the transverse automatic motion to the top slide.

1606. Lathe and appliances for ornamental turning (working). Made by Messrs. Holtzapffel & Co. Received 1904. Plate X., No. 3. M. 3364.

This is a foot lathe for ornamental turning; the standards and treadle driving gear have, however, been removed and the machine is shown with an oval chuck in use turning elliptical work.

The fast headstock has a parallel mandrel with long bearings, but for most classes of work the mandrel is pushed back until a cone on it thrusts against the front bearing, where it is retained in position by a long collar fitting over the back end and fixed to it. The face of the cone pulley is perforated with circles of holes to act as a division plate for setting out or spacing work. To the small end of the step pulley is attached a disc with a thick rim pierced with 72 large holes in which pins can be inserted, to limit the rotation of the mandrel by coming into contact with an adjustable stop; this is for the purpose of producing segmental ornament, the mandrel being

turned through the required angle by hand or by a disconnecting tangent-screw and wormwheel, which may also be used for dividing. For work between centres a poppet head or loose headstock is provided; there is also a collar plate to give circumferential support to long objects when being bored from an overhanging end.

The oval chuck in its present form was patented in 1764 by Messrs. J. Williamson & J. Spackman, but chucks identical in principle. although slightly different in construction, were in use in 1700; the earliest turned ovals were, however, copied from a guide in a rose engine (*see* No. 1597). The chuck shown consists of a back plate screwed on the mandrel nose, and having on its face a front plate carrying the work and sliding between V guides. The front plate is controlled by means of studs passing through slots in the back plate, and having flat cross-pieces, which are in contact with the exterior of a ring projecting from a frame secured to the face of the headstock at the level of the centres by pointed screws and capable of horizontal adjustment to obtain any required eccentricity. The work thus receives an oscillating motion across the mandrel, which causes it to recede from the tool twice per revolution, in such a manner that a stationary tool cuts on the work in any position true ellipses, the limit being a straight line when the point of the tool is at the centre of the mandrel. These curves have a constant difference between their major and minor axes, equal to twice the eccentricity of the guide ring; the strip between any two ellipses is consequently not exactly uniform in width. A hand tool can be used on the rest as shown, but owing to the importance of constancy of height such work is simplified by the use of a slide rest.

For cutting the short screws chiefly required for fastening together the parts of ornamental work, the mandrel is traversed and the tool held stationary. For this purpose the collar on the back end of the mandrel is replaced by one of a series of short guide screws; below this and attached to the headstock is a plate having around its edge segments cut with threads corresponding with the guide screws, and this plate is mounted on an eccentric pin by which it can be put in and out of gear.

When screws or helices of greater length than the guide screws or of other pitches are required, the longitudinal screw of the slide-rest (not shown) can be connected with the mandrel by change wheels.

1607. Prismatic lathe. Lent by Messrs. Smith & Coventry, 1897. M. 2966.

This construction of lathe, patented in 1891 by Messrs. Dahlgren & Svensson, of Christiania, is for turning such sections as squares and hexagons. This it accomplishes by revolving the work between centres in the manner usual in turning, while using as a cutting tool a revolving cutter with several cutting points arranged in a circle and uniformly rotated. The speed of the cutter depends upon the number of facets to be produced and upon the diameter of their path; they revolve in the same direction as the work. Although the facets produced are not mathematical planes, the deviation can be reduced to an amount that is scarcely perceptible with a straight edge.

In the example shown, which is engaged in cutting hexagons, the revolving tool consists of three cutters, carried on a spindle at the back, revolving at twice the speed of the work, which is carried between headstocks mounted on a saddle by which the distances between the work and cutter axes can be altered; both headstock spindles are connected by gearing with a lower belt-driven shaft, swinging arms being introduced to carry change wheels and give a flexible connection. The headstock holding the work is moved longitudinally by a screw, thus automatically feeding the work along; this headstock also has an arrangement by which the correct setting of the work in relation to the path of the cutters can be effected.

An adjacent diagram model (working) demonstrates the action of the machine.

1608. Self-centring four-jawed chuck. Lent by Messrs. Wellington & Co., 1887. M. 1866.

This lathe chuck, patented by Messrs. Clark & Wellington in U.S.A. in 1882, has four adjustable jaws, moved in and out by four radial screws The screws are geared together by means of a ring with bevel teeth, housed within the hollow rim; this ring gears into four bevel pinions, one upon each screw spindle, so that all four screws work simultaneously when one is turned.

1609. Capstan slide-rest. Lent by Messrs. Wm. Muir & Co., Ltd., 1907. M. 3486.

This is an example of the capstan rest for lathes, patented by Mr. A. Muir in 1892. Ordinary tools are used and the work may be operated upon close up to the face-plate or chuck.

The capstan block is square and has a slot along each side in which four different tools may be clamped by set screws in the usual manner. This block turns on a pivot and is secured by a central clamping screw, while a spring stop in the base, engaging with grooves formed in the under side of the capstan, holds it in the correct position for each tool.

1610. Noble's expanding mandrel. Lent by the Britannia Co., 1887. M. 1851.

This lathe mandrel is adjustable so that it can be set to fit various diameters of bore, instead of a separate mandrel being required for each size. This is effected by means of three wedges, whose outer edges form parts of a cylinder, sliding in dovetail grooves cut on the enlarged central portion of the mandrel. The bottoms of the grooves are inclined at the same angle as the wedges, so that when a nut, which forms part of the lathe carrier, is screwed on to one end of the mandrel, it forces the wedges along until they fit the bore of the article to be turned. The mandrel is released by screwing up a nut on a left-hand thread at the other end. The diameter of this specimen ranges from 1·625 in. to 1·875 in.

1611. Expanding mandrel. Lent by Messrs. H. B. Barlow & Co., 1892. M. 2467.

This mandrel, patented by Messrs. A. B. and H. B. Barlow in 1884, consists of a tapered spindle having sliding upon it three correspondingly tapered wedges, which can be pulled along by a nut screwed on the larger end of the spindle and embracing a projection formed on each wedge. The work to be turned is carried on the cylindrical external surface of these wedges, which are prevented from slipping on the spindle by three fixed keys. An annular spiral spring keeps the wedges in position when the mandrel is slacked back. The example shown is for work about 2 in. diam., and has a range of ·05 in. diam. above or below this size, but by using the split bush shown the effective diameter is increased to 2·5 in.

1612. Tool for spherical boring. Contributed by R. Bodmer, Esq., 1857. M. 66.

This is a full-sized model in wood of a tool patented by Mr. Bodmer in 1841, for boring out connecting rod ends and similar objects to a spherical shape, so that brasses fitted in them should be able to swivel to such an extent as to adjust themselves if the crank-pin were out of line.

The object to be bored was fixed to a lathe face-plate and the tool shown carried in the slide-rest. The cutter is held on a swivel that is carried by the tool, and is slowly fed round and rotated by spur and bevel gearing as the boring proceeds. The centre of the swivel must be on the central line of the lathe if a truly spherical seat is to be produced.

1613. Weston's ratchet brace. Lent by Messrs. Nettlefolds, Limited, 1888. M. 1945.

This is an example of a ratchet brace, patented by Mr. T. A. Weston in 1866, for working drills for metals. It differs slightly from those in common use in having larger and stronger ratchet teeth. Two ratchet wheels are employed, placed with the teeth of one in advance of the other, so that the two pawls may act alternatively on them. By this arrangement the use of very fine pitched ratchet teeth is avoided.

1614. Drilling machine. Formerly the property of James Nasmyth. Received 1899. M. 3065.

This small machine resembles the large power drills constructed by Messrs. Nasmyth & Gaskell about 1840; at that time they were, however, also constructing machines with the spindle overhanging as now almost universally arranged.

The framing shown consists of a base with two columns supporting a cross girder which carries the drill spindle and its driving and feeding arrangements. The power is transmitted through mitre wheels to the drill spindle, which is fed downwards by a central screw supported by a crosshead carried on two small wrought-iron columns. This screw is fitted with a winch handle for feeding it downwards by hand; there is also an automatic feed given by a vertical shaft that is intermittently rotated by a pawl worked by an eccentric on the lower end of the spindle sleeve. In the larger machines step-driving pulleys were used, also an independent work table, with horizontal screw adjustment in two directions.

1615. Engraving of Whitworth's self-acting drilling machine. Contributed by Messrs. Joseph Whitworth & Co., 1857. M. 103.

This shows a drilling machine fitted with the self-acting feed motion patented by Sir Joseph Whitworth in 1837.

The spindle is driven by bevel gearing in the usual manner; it has a screw thread cut on its upper part which gears with two worm wheels mounted on and keyed to transverse shafts. To the outer ends of the shafts friction rollers are fixed, fitted with brake blocks which are drawn together by a rod with right and left hand screw threads. When the drill spindle revolves the worm wheels are rotated by the screw, but when the rollers are gripped by the brake blocks, the worm wheels are retarded and caused to act as a nut by means of which the spindle is advanced. A hand wheel on one of the transverse shafts is provided for rapidly withdrawing the drill, which it does by using the screw as a rack.

1616. Drilling machine for watch plates. Contributed by R. Roberts, Esq., 1860. M. 148.

This machine, patented by Mr. Roberts in 1848 as a "normal" drill, is an arrangement for drilling a large number of holes in the frame plates of clocks and watches, to a standard template as regards position.

The drill spindle is carried on a rigid bar and on this bar also is a frame that carries the guide-pin, or stop. Parallel to the fixed bar is a similar bar supported on trunnions and provided with a counterbalance weight, on this bar are clamped two headstocks connected together by an intermediate spur-wheel. The headstock nearest the trunnion carries a chuck that holds the frame that is to be drilled, while the outer headstock carries a plate that has been drilled with uniform holes into which the guide pin will fit. This template is an enlarged pattern of the frame to be drilled, the ratio of enlargement being determined by the position of the two chucks on the swinging bar, which is graduated for their correct adjustment. When holes

of different diameters have to be drilled, the drill only is changed. On one of the templates shown the pitch circles of the train to be drilled for are visible.

1617. Model of multiple drilling machine (full size). Presented by Andrew Shanks, Esq., 1864. M. 957.

This machine was patented by Mr. Shanks in 1861 as a means of drilling simultaneously a large number of holes close together, as in condenser tube-plates. The difficulty in such machines is to get the driving mechanism for each spindle within the restricted space between the centres, while retaining the power of altering the pitch.

In the arrangement shown each spindle has at its upper end an overhanging crank which is also somewhat bent so that it clears the adjacent cranks. All of the crank-pins fit into holes in a connecting plate, which is moved in a circular path by a similar crank arranged above it and driven by power. In the patent specification arrangements are shown for altering the positions of the holes.

1618. Model of slot-drilling machine. (Scale 1 : 4.) Presented by the Institution of Civil Engineers, 1868. M. 1072.

This machine, patented in 1855 by T. B. Sharp and R. Furnival, is for cutting elongated holes by means of a revolving tool, somewhat resembling a drill, slowly travelling to and fro over the length of the required slot.

The machine has a box bed supported on standards, with an adjustable table projecting in front to carry the work, which remains stationary during the operation. The overhanging drill headstock slides along the top of the bed and the rotary motion is transmitted to the tool by gearing from a longitudinal feather shaft driven at one end. The longitudinal reciprocating motion of the headstock is obtained from an adjustable horizontal crank and a connecting rod, which drive a screwed spindle passing through a nut on the under side of the head, so that both the length and position of the slot can be adjusted. The crank motion is worked from a countershaft below the bed, driven by a belt from the upper shaft, which drives the crank by worm gear and an eccentric pinion gearing with an elliptical wheel on the crank disc; in this way the angular velocity of the crank is varied so as to render the traversing motion of the drill fairly uniform. The intermittent vertical feed motion to the drill is transmitted through a friction clutch and worm gear from a ratchet wheel actuated by a cam on the crank disc; this clutch is released when the drill is being raised or lowered by hand. A continuous vertical feed, which can be used for ordinary drilling, is provided by worm gear and another clutch driven by a belt from the upper shaft.

1619. Planing machine. Contributed by R. Roberts, Esq., 1860. Plate X., No. 5. M. 463.

This machine, made by Richard Roberts in 1817, is said to be the first one made for planing metal; it is evident from marks on the bed that it was made without the assistance of such an appliance. The work is secured to a table which moves to and fro on a straight bed, under a fixed tool which is capable of being traversed so that, by the two motions, plane surfaces are produced as the tool makes successive cuts. The table is provided with bolt holes for securing the work and is moved by means of chains wound on a drum rotated by hand; the guiding surfaces are a narrow flat face on one side and an inverted V on the other. The cross slide is supported on two standards bolted to the bed, and screws are provided for adjusting its height; it has an internal screw for traversing the tool rest, which is capable of angular adjustment and has a hand feed motion. The tool is held by a hinged clamp. The table is 52 in. long and 11 in. wide.

1620. Planing machine. Made by Messrs. Joseph Whitworth & Co., 1842. M. 3561.

This self-acting planing machine was patented in 1835–9 by Sir Joseph Whitworth and was known in the shops as a "Jim Crow" because of its reversing tool-holder.

A leading screw in the middle of the bed of the machine, driven by fast and loose pulleys and a three-bevel wheel reversing arrangement, transmits motion to the V-guided table by means of a pair of antifriction wheels on its underside, mounted on studs perpendicular to the axis of the screw with the thread of which their rims engage. The cross slide is supported on and is actuated by two vertical screws connected by bevel gear and shaft fed by hand. The swivelling tool box is on a screw on the cross slide and is fed by a pulley and ratchet actuated by a band from a rocking pulley on the same shaft as a pinion moved by a rack rod with stops on the bed. By guide pulleys the band also turns the tool-holder through 180 deg. at the end of each stroke so as to cut in both directions. The bed of the machine is 4 ft. by 15 in.; the maximum height under the tool is 12 in.

An engraving of a similar machine is shown near.

1621. Planing machine. Formerly the property of James Nasmyth. Received 1899. M. 3063.

This small machine was built in 1857 by Messrs. J. Nasmyth & Co., but in its arrangement and detail it is almost identical with some of the larger machines made by them about 1840. At that time, however, the firm was making rack-moved planing machines with quick return motions, but for sizes up to 3·5 ft. wide by 8 ft. travel, the gear shown was considered to give a quieter and quicker action.

The frame is a somewhat massive casting, with two V-guides with the apex uppermost, so that, although not retaining the oil so readily as the later form, they did not form receptacles for dirt. The two standards are bolted to the main framing and are connected by a cross girder which carries a central screw by which the height of the cross slide is adjusted; the cross slide has an internal traversing screw, for moving the tool rest which is capable of angular adjustment and has a hand-feed motion. The tool-holder has the usual hinged box for preventing damage to the tool in the return stroke.

The table of the machine is a single casting, with slides planed on its lower surface corresponding with the fixed guides; the upper part of the table has six longitudinal T-headed grooves for receiving the bolts for securing the work. The table is moved to and fro by a mangle-wheel motion, there being two chains passing from the lower side of the table over fixed guide pulleys down to a chain wheel, round which they pass in opposite directions before being secured; the shaft of this wheel carries at one extremity a wheel with lantern pins, or teeth, into which a small pinion on the driving shaft gears. The pinion end of this shaft is carried in a sliding bearing, so that the pinion gears alternately inside and outside of the segmental lantern wheel, thus reversing the motion after a definite length of travel has been effected. The length of stroke can be permanently altered by removing from the mangle wheel some of its teeth, which are single pins secured by nuts. In the machine shown, a hand-driving mechanism has been added and the loose pulley removed. The transverse travel of the tool box is automatically given by a pawl feed, receiving its motion from the lateral play of the pinion shaft.

1622. Specimens of curved planing. Contributed by R. Roberts, Esq., 1860. M. 159 & 162.

The two bronze specimens are examples of helical planing with pitches of 11 and 37 in. respectively. They were prepared on an ordinary planing machine, with the work held in a headstock which made a partial revolution during the travel of the table, in a way now common in rifling machines.

The other specimen is a reed moulding cut in cast iron, to a circular arc. It was done on an ordinary planing machine, on the table of which was placed a second table or sector, centred on a stud attached to the stationary bed. The sector was attached by two chains to eyes secured to the table, which by its motion caused the sector to swing horizontally; the work was secured to the sector at a distance from the stud corresponding with the radius required.

1623. Shaping machine. Formerly the property of James Nasmyth. Received 1899. M. 3064.

This small bench machine, for working by hand, represents an early form of shaper. The driving shaft terminates in a disc in which is a slot carrying an adjustable crank pin, by which the length of the stroke can be varied. This pin is fitted with a block capable of sliding in a vertical slot formed on a horizontal ram that carries the tool box; the ram works in adjustable V-guides, and is fitted with a vertical slide in which the tool box is fed by hand. The work table slides on guides on the front of the main casting and is traversed by an internal screw driven by hand power, or automatically by a pawl feed motion rocked by an eccentric on the main shaft. The table is fitted with a vice, and there is also an arrangement for holding square and hexagonal nuts while being shaped.

1624. Wall diagrams of engineers' machine tools. Lent by Messrs. W. Hulse & Co., 1890. M. 2351.

These diagrams were prepared to illustrate a paper read before the Institution of Civil Engineers, by Mr. W. W. Hulse, in 1886.

Heavy Lathe.—Three views are shown of a heavy lathe of 40-in. centres. The power is transmitted from a step pulley through intermediate gearing to a spur ring formed on the back of the face-plate, and having both internal and external teeth, a considerable range of speed being obtained by the use of sliding shafts and pinions. The bed carries two independent saddles and four top rests, arranged for simultaneous working. The saddles are moved by two fixed screws, around which work nuts carried beneath the saddles and receiving their motion from a central shaft running within the bed.

Horizontal Boring Lathe.—This is a break lathe, with a heavy boring bar to which the tool-holders are secured. For boring, the cutters are held in a circular head which is traversed along the bar by an internal screw. When facing has to be done, the tool is held by an arm secured to the bar, and receives a radial movement from a screw driven by a star wheel. The table, which is arranged in the gap of the lathe, can be screwed upwards or downwards by power. It has guides for longitudinal and transverse movements, so that one setting of the work is sufficient for all holes parallel in direction.

Planing Machine.—This represents the most usual form, in which the work is secured to a horizontal table which is screwed backwards and forwards by power, while the cutting tool is carried in a rest that receives the feed motion, vertical or transverse as desired.

In the machine illustrated the table slides on horizontal V-guides, and is kept down solely by gravity. The driving screw is driven through bevel wheels at one end of the machine, a shifting belt reversing the motion. There are two independent tool-holders, fed by screws in the horizontal guide that carries them; this guide can slide vertically on guides formed upon the main standards. At the top of the left standard are fast and loose pulleys by which power is transmitted for quickly raising and traversing the tool boxes when changing work; the ordinary feed movements are given by a tappet motion driven by the table.

Vertical and Horizontal Planing Machine.—In this machine the work is secured to a fixed table in front of the machine, while the tool is held in a slide that can be driven by power in a horizontal or vertical direction. This type of machine enables facing to be done on castings that are too large to pass between the standards of the ordinary planer.

The horizontal guides, two in number, are secured to three massive standards; on these guides move saddles, driven by connected screws arranged one in each guide. These saddles carry a vertical guide, upon which slides the tool-holder. This tool-holder is driven by a screw, arranged between the vertical guides, and the weight of the holder is counterbalanced by a chain and weight. Power to drive these saddles to and fro on the horizontal guides, or to move the tool rest up or down, according to the cut required, is supplied through the usual three-bevel gear reversing arrangement.

Vertical Milling Machine.—In milling, the work is done by cutting edges formed on a revolving cutter; owing to the number of edges in use the output of such a cutter is much greater than would be obtainable with a single-edged tool.

The feature of this milling machine is that the vertical spindle that carries the cutter does not increase its overhang from the front bearing as the spindle is fed downwards. This is accomplished by carrying the spindle on a square ram, adjustable in vertical guides formed on the main standard, so that when the spindle is lowered the ram goes with it. The spindle is rotated by a spur wheel secured to it, and gearing with a long vertical pinion by which the driving power is transmitted from the usual back gear irrespective of the position of the ram. The table of the machine has a circular feed motion, and two horizontal feed motions in directions at right angles. A small centrifugal pump continually projects lubricating water upon the cutter when the machine is running.

1625. Model of reciprocating saw. (Scale 1 : 5.) Made by MM. Regnard Frères. Received 1892. M. 2444.

This is a model of a machine saw for intricate cutting in metal sheets or plates. A full-size saw blade of the description used is also shown together with a specimen of the work produced, but several sheets are usually cut simultaneously, and iron over 1 in. thick presents no difficulty. Owing to the ease with which the saw blade can be inserted the machine is adapted for work that a band saw will not perform.

The machine consists of a planed cast-iron table supported on four legs, and carrying a heavy double-armed bracket which holds the guides for the saw blade both above and below the table. Concealed in the bracket are two horizontal levers turning on central gudgeons, one above and one below the table. These levers are connected at one end by the saw blade carried in adjustable straining holders, and at the other by a vertical link. The upper lever, and through it the lower one, are reciprocated by a connecting rod from a crank on a shaft driven by a stepped pulley at the back of the machine. The pulley is formed with a cone clutch, which is under the control of a treadle and a hand lever, for easily starting and stopping the saw from the front.

1626. Wheel-cutting engine. Made by Manuel Gutierrez. Received 1900. Plate X., No. 4. M. 3095.

This machine, for cutting the wheels of clocks, is stated to have been made in Madrid in 1789.

The blank wheel having been prepared, the spaces between the teeth are cut by a disc ·6 in. diam., with its formed edge scored by a graver so that it acts as a fine milling cutter. This cutter is fixed on a spindle rotated by spur gearing, from a hand-driven countershaft carried between centres on a frame that swings between stops, but is secured in an adjustable slide that permits of skew teeth being cut. This head is carried on a slide so that it can be set to suit the diameter of wheel required, and there is a screw feed for adjusting the depth of tooth.

The wheel blank is secured to a vertical spindle, which carries near its lower end a disc 5·9 in. diam., extensively divided on both faces, wheels of even 47, 49, 51, and 58 teeth being provided for. The upper end of this spindle runs in a conical bush, and the lower one on a cone centre.

1627. Wheel-cutting engine. Lent by the Lancashire Watch Co., 1905. M. 3422.

The earliest method of manufacturing clock wheels was to mark off the blank by means of a radial ruler on a pin centred in a plate divided concentrically to numbers of teeth in common use; the teeth were then filed out by hand. Robert Hooke, F.R.S., about 1670, mounted the divided plate so that it could be rotated, added an index, and applied a revolving file (*i.e.*, a milling cutter) to the edge of the blank. Various improvements took place in the succeeding century; the tool, in the form shown known as the Lancashire pattern, is due to John Wyke (*b.* 1720, *d.* 1787) of Prescot, a seat of the watch industry from early times.

A circular plate, divided for 55, 60, 63, 64, 70, 72, 75, 80, and 100 teeth with an adjustable spring index, is mounted on a spindle in a cone bearing below and a split collar above, in a cast-iron frame on three legs; on this spindle the wheel blank to be cut is clamped. The cutter is on a spindle driven by a gut band, and mounted in a frame that can be swung out of the way while the blank is being set for a fresh tooth. The bearings of this frame can be slightly tilted so that skew teeth can be cut. The whole is adjustable by a screw in V-guides on the frame to admit of blanks of different sizes.

This machine has now practically been superseded by a tool in which a large number of wheels are cut simultaneously.

1628. Gear cutters. Contributed by R. Bodmer, Esq., 1857. M. 51.

These circular steel cutters or milling tools, patented by Mr. Bodmer in 1839 as a means for cutting the teeth of small spur-wheels, racks, &c., are now in general use for the purpose of cutting gearing of all sizes. The cutters have teeth very similar to those of a saw or a file, but shaped to the profile of the spaces between the teeth of the wheel to be cut.

1629. Worm gear cutters. Contributed by R. Bodmer, Esq., 1857. M. 52.

These milling tools for cutting worm wheels were patented by Mr. Bodmer in 1839. The cutter or "hob" is a steel worm identical in shape with the worm with which the required wheel is to work; it has, however, teeth formed on it similar to those of an ordinary milling cutter. The worm-wheel and the cutting worm are rotated at their correct relative speeds and fed into contact; the cutting worm then excavates the spaces required for the threads of the actual worm to engage in, and leaves accurately formed teeth of the correct shape for gearing with the worm. As the cutting proceeds, the milling worm is fed further into the wheel, until the required depth of space is obtained.

1630. Woodruff's keys. Lent by the Woodruff Keying Co., 1892. M. 2471.

These keys are intended for general use in securing wheels, &c., to shafts and also for cases requiring a feather key.

The key consists of a segmental disc of steel, and the keyway in the shaft is milled out to the same curvature and width as the disc, but shallower by the amount to which the key should project. Such keyways are very cheaply formed by the special milling machine illustrated, in which the milling cutter spindle can be fed down by a lever until the regulation depth, as determined by a stop, is reached. The keys are of standard sizes, agreeing with the cutters employed, and a key will adjust itself in its bed so as to correspond with any taper given to the keyway in the wheel or boss. Several sizes of keys and cutters are shown, and also an adjustable stay for supporting a shaft while the keyway is being cut.

1631. Model of double grindstones. (Scale 1 : 4.) Contributed by Messrs. Wm. Muir & Co., 1858. M. 286.

This arrangement of workshop grindstones was patented by Mr. William Muir in 1853, and is a simple means of keeping them true. The two stones are mounted on parallel shafts in the same trough and in contact with one another, but they are made to revolve at different velocities so that at the point where their peripheries are in contact there is a mutual rubbing action that tends to keep them cylindrical. To prevent grooving a lateral motion is also given to one of the stones by a worm and wheel that rotates a cam that gives this motion to the axle of the stone. As the grindstones wear down, the bearings of their shafts are caused to approach each other by a pair of right and left-handed screws.

1632. Emery wheels. Contributed by D. Fisher, Esq., 1866. M. 1014.

These are samples of composition wheels, patented by Mr. Fisher in 1856, for grinding and sharpening tools. Samples of the composition in the form of bars and rods, to be used as files, are also shown.

1633. Workshop tool grinder. Lent by Messrs. Luke & Spencer, 1890. M. 2294.

In this machine an artificially-prepared emery disc is employed in place of a grindstone and is run at a surface speed of 3,000 ft. per min. A small centrifugal pump driven by the machine maintains a continuous supply of water on the grinding surface to keep the tool cool. Emery discs are cleaner and safer in their action than a grindstone and remain true much longer. When trueing-up is necessary, a tool holding a small black diamond, and carried in a slide which can be clamped to the table, is employed, but as a surface speed of only 100 ft. per min. is then desirable, gearing and a hand wheel are fitted for giving this lower speed. For rapid grinding, the rougher surface left by the rotary steel hacking cutter is more effective than that left by the diamond.

1634. Engraving machine. Presented by Mrs. H. T. Ryall, 1896. M. 2940.

This is a small lining machine, designed by Mr. H. T. Ryall, the engraver, for filling in skies on steel or copper plates, the ruling and spacing of such parallel lines being exceedingly difficult without some mechanical assistance.

The machine consists of a wooden frame, supported at the four corners so that long plates can be worked upon; upon the frame as a guide slides a saddle, and along the saddle slides a small carriage that carries the graver, The carriage is moved to and fro by the pull of a band moved by a pulley and winch handle at the right-hand side, the carriage being kept down on its guides by the finger of the left hand. A cross-bar working in inclined slides supports the graver clear of the plate when desired. The motion of the saddle is controlled by a lever on it, which is connected to a steel strip which works in a clamp on the frame. The clamp is tightened, and the lever moved, so moving the saddle through a small distance; the clamp is then released, and the lever moved back, and so on, a very fine feed being thus obtainable, and one of varying amount as the motion of the lever is controlled by an adjustable screw.

In later machines the motion of the carriage and of the saddle are usually both given by screws, and the general construction is in metal, and much more massive than here represented.

1635. Saxton's medallic engraving machine. Lent by the Society of Arts, 1899. M. 3071.

This is an appliance for engraving or drawing, on a flat surface, a shaded representation of an object that is in relief. A machine of this class was

introduced in 1830 by Mons. Achille Collas and was subsequently used in preparing the engravings for "Le Trésor Numismatique et de Glyptique."

The machine shown, however, was made by Mr. Joseph Saxton, and it embodies an invention by which distortion of the picture is reduced; a similar modification was introduced and patented in 1832 by Mr. John Bate (*see* No. 1636).

The machine consists of a base upon which a work table can be moved horizontally by a leading screw with a ratchet wheel feed, which can be made as fine as ·0003 in. if required. The tracing and engraving points are mounted on a carriage which is slid to and fro by hand along a triangular bar guide above the tracer; the tracer is attached to one arm of a bell-crank lever carried by this slide, and the other arm of the lever carries a light frame containing the graver. By this arrangement the vertical motion of the tracer, due to relief in the copy, causes an equivalent horizontal displacement of the graver; it was by a modification in the form of the bell-crank and by the use of an oblique tracer that the distortion previously resulting was avoided. In the return stroke of the carriage the tracer and engraver are lifted clear of the pattern and plate, respectively. From there being no means of putting pressure on the graver it is probable that the resulting plate was subsequently etched.

The work table carries two face-plates geared together by an intermediate wheel so that corresponding angular adjustments can be immediately effected on each; numerous other accessories are provided which, together with a sample of the work, are also shown.

1636. Engraving machine. Woodcroft Bequest, 1903.
M. 135–6.

This engraving machine, or "Anaglyptograph," was patented in 1832 by Mr. John Bate. It is intended for engraving or drawing on a flat surface a shaded impression that shall represent the appearance of a copy that is in relief, such as a medallion.

It consists of a cast-iron bed supported on three legs, and carrying on V-guides two sliding tables, and also a transverse frame which supports and guides a light three-wheeled carriage. The tables are connected by a screw which moves them simultaneously; on the higher table is secured the object to be copied, while on the lower one is the copper plate that is to be engraved. The carriage holds a braced frame, which has a feeling point touching the pattern, and a diamond-tipped engraving point on the copper plate. When the carriage runs on its rails the graver cuts a straight line on the copper plate; the tables are then moved a small distance by the screw, and a parallel straight line is drawn, and so on. The feeling point, however, is at the same time moving over the irregular surface of the copy, and by levers the two points are so connected that a rise on the copy causes a curving outwards of the line being engraved, and a fall a curving inwards.

The attached prints from plates engraved in this manner show that a very pronounced appearance of relief is given by these minute variations in the pitch of the lines at various parts. The result resembles contouring but the method is quite different, and mechanically much more convenient.

1637. Instrument for dividing scales. Presented by the Commissioners of Patents, 1857. M. 127.

This is a simple form of dividing engine, for use in marking the divisions on scales or rules. A nut travelling on a long screw turned by hand, carries a pointer and vernier that indicate the position upon a fixed brass scale. The nut also carries a lens to assist in the reading of the vernier, and a guide for the pen used in preparing paper scales. There is also a jointed tool-holder, carrying a graver for use in engraving other scales, and there is a swivelling arrangement for use in preparing diagonal scales.

1638. Donkin's dividing engine. Lent by Bryan Donkin, Esq., jun., 1886. Plate X., No. 6. M. 1715.

This machine was constructed in 1826 by the late Mr. Bryan Donkin, F.R.S., to facilitate the graduating of mathematical scales, and it was also used for originating a remarkably accurate screw thread. The distinctive feature of the method followed consists in the employment of a compensating arrangement which can be so adjusted as to neutralise any irregularities that, by careful optical measurement, have been found to exist in the leading screw of the engine. Maudslay had, in 1810, used a compensating lever to distribute uniformly a total inaccuracy of $\frac{1}{16}$ in. over a screw that was 7 ft. long, but by Donkin's arrangement the corrections could be either plus or minus and were made for each 25 turns of the screw, in accordance with the local variations that were found to exist in the early leading screws, instead of being a single correction that gave a correct average, but that neglected the intermediate variations.

As now fitted up the machine is arranged as a lathe, the compensated leading screw, which is 24 in. long with 50 threads to the inch, being situated between two deep frames, with a slide and tool-holder fixed above. The new screw to be cut is carried between centres at a higher level, but being about 3 ft. in length necessitates the cut being done in two settings. The work is rotated by a winch handle, and the guide screw is geared with it in the usual way. The guide screw by means of a clamp nut traverses the saddle, upon which is fixed an upper rest carrying the tool, but the connection between these two rests is by the short arm of a right-angled lever, the long arm of which is horizontal and 50 times the length of the short one. The lever is carried by the lower rest, but any rise or fall of the long arm causes a slight movement of the upper rest upon the lower one. Any slackness is taken up by a spring which tends to move the upper rest in the direction that will depress the long end of the lever. The free end of the lever is fitted with a knob which rests on the compensating bar, fixed to the main framing some distance below the guide screw. This bar is of brass with 24 plates ·5 in. wide, each adjustable by its own set screws, while the whole bar is also capable of adjustment for an overall correction.

Having by inspection determined the inaccuracies of the guide screw at 24 points in its length, and at each point adjusted its compensating piece so that the lever shall move the upper rest to the extent necessary to counteract the determined inaccuracies of the screw, the 24 compensating pieces so adjusted were slightly smoothed at their corners so as to obtain a uniform line. The deviation of this line from a straight line parallel with the bed shows, magnified 50 times, the irregularities in the screw which are being corrected by the arrangement.

The determination of the inaccuracies of the guide screw were made when the headstocks and the centres of the long screw being cut were removed, and in their place stood the table carrying the two microscopes and the engraving tool, now standing at the other side of the machine. On the top slide of the engine was secured a polished brass strip or undivided scale, and one of these is now visible in position. On this scale marks were made, say 24 in. apart, and then by trial this length was bisected, again bisected, and so on, the identical readings with both halves of the distance under the cross wires of the two microscopes securing a very accurate result. The difference between the position of the slide for these divisions and the position as determined by the guide screw showed the correction required.

The rotation of the guide screw was performed by a ratchet gear, shown in the case mounted on the wooden headstock. The motion wheel has 500 teeth and is moved by a pawl which is thrown out of gear by an eccentric on the hand-wheel shaft. On this shaft is a plate and stops by which the subdivision of the circle can be performed.

In 1840 Mr. Donkin constructed a larger and improved form of this machine, but the general action and arrangement is almost identical with this one.

1639. Screw stocks, dies, and taps. Contributed by Messrs. Joseph Whitworth & Co., 1857. M. 54.

These tools embody the improvements patented by Sir Joseph Whitworth and John Spear in 1840.

The set of dies consists of three pieces, a wide one which acts chiefly as a guide, and two narrow ones which act as true cutting tools or chasers. The two cutting dies have each one cutting edge, but one cuts during the right-handed rotation and the other with the left. Both dies are simultaneously closed in radially by a notched cotter, which is tightened up by a nut as the screwing advances. The master tap, by which the dies are cut, is made larger in diameter than the ordinary tap by twice the depth of the thread, so that when commencing to screw, the dies touch all round the rod to be screwed, and are therefore certain to start a true thread. As the screwing proceeds, the dies act more and more by their corners or cutting edges only, so obtaining "relief" to the cutters, and improving their cutting power. Dies for various threads can be fitted in the stock, and they are held in position by a removable cover-plate.

The taps are formed with three wide longitudinal grooves milled in them, the section left being such as to give three true cutting edges of 90 deg., and the necessary relief is obtained by "backing-off" the thread following the cutting edges. The shank of the tap is reduced so that it will pass through the hole tapped. The master taps shown have eight narrow grooves, owing to the dies to be cut being in pieces.

The adoption of the Whitworth standard screw threads which gave the present uniformity was hastened by the superiority of this tackle over that formerly in use.

1640. Screw taps. Contributed by R. Bodmer, Esq., 1857. M. 53.

These "convolute" taps, patented by Mr. Bodmer in 1841, are very similar to those of Whitworth. The top of the thread is eased in a convolute form, and the bottom and sides of the thread are also tapered and relieved in the same way, so that the tap may cut like an ordinary turning tool.

1641. Screwing machine. Contributed by W. E. Newton, Esq., 1861. M. 671.

This is a screw-cutting machine, patented in U.S.A. by Messrs. Moore & Madison in 1856, for cutting screws by hand or by power. The dies are held in a clamp which slides freely on two fillets, one on each side of a trough. The clamp is provided with a screw and a graduated scale for closing and setting up the dies, and a lever and latch for quickly opening them. The rod or bolt-blank to be screwed is held in a pair of jaws like a lathe chuck, and is caused to rotate. The machine can also be used for tapping nuts, a cross bar with a square recess or socket being then used to hold the nut stationary, and the tap being held by the jaws and rotated.

1642. Screw rolling machine. Contributed by Mr. Elliot, 1860. M. 384.

This machine, patented in 1851, is intended for making single or multiple screw threads of different diameters from the same set of dies, and for producing the thread, whether square or angular, by rolling compression. Two steel plates or dies, having on their faces longitudinal grooves of the shape and pitch of the required screw thread, are placed one above the other at a distance apart suitable for the diameter of the screw. The upper die is attached to a block which can be raised or lowered by a screw, and the lower one is attached to another block which slides in horizontal guides and receives a reciprocating motion from a crank and connecting rod driven through spur gearing. The dies are adjustable in their blocks and are set so that their

grooves are inclined at opposite angles to the direction of motion of the lower die, equal to the angle of the required thread. The rod or blank is placed between the dies, the upper one forced down upon it, and motion given to the lower one whereby the blank is rolled between the faces. Specimens of the screws produced by this process are shown.

1643. Screw gauges. Lent by Messrs. Taylor, Taylor & Hobson, 1893. M. 2551.

These specimens show the system of standard gauges introduced to ensure that the screwed connections of photographic apparatus shall be interchangeable.

No. 1 is a double calliper gauge for external threads—one side gives the standard in this case 1·5 in. diam., and the other 1·499 diam., the difference being the amount allowed on external screws to secure an easy fit and absolute interchangeability, any work exceeding these limits being rejected. No. 2 is a double gauge for internal screws, one end being ·001 in. larger than the standard so that any screw cut to it shall readily fit any screw passed by the external screw gauge. No. 3 is the chaser employed for cutting the threads, and it is equally capable of cutting both internal and external threads. It has two grooves, of the shape of the thread, cut on it externally, and is provided with a central hole by which it can be attached to a tool-holder. One-fourth of the circumference is cut away so giving two cutting edges, one of which is used for external screws and the other for internal ones.

To overcome the difficulty of entering these fine threads and also to avoid the risk of stripping them, the first half of the revolution of the thread—where it is incomplete—is cut away, so giving an abrupt commencement but a thread of full strength. The internal threads are treated in the same way, and an arrow head is stamped on the two portions so that they can be placed together in the position in which the relieved threads will at once engage. Nos. 4 and 5 show a pair of threads so treated. No. 6 is a standard screwed ring in steel provided with an index mark on each side. Its thickness is such that, when screwed on, the index marks the commencement of the complete thread, so that by marking and finishing fittings to this gauge it is secured that all fittings shall screw up to the same position, thus ensuring that lenses or diaphragms shall occupy their intended parts in any camera.

1644. Parallel vice. Lent by J. Parkinson, Esq., 1890. M. 2349.

In this vice, patented by Mr. J. Parkinson in 1885–6, the screw travels with the front jaw and, by a lever at the side, the stationary half-nut which locks into the screw can be lowered out of gear, allowing the vice to be quickly opened or closed to its full extent, while when the nut is permitted to engage, the necessary powerful grip is obtained by a slight turn of the screw. A spring is fitted which presses the nut into gear and the thread employed is of the buttress form. The front arm having a simple sliding motion, the jaws always remain parallel.

1645. Caulker for pipe joints. Presented by C. Wheeler, Esq., 1883. M. 1545.

This is a tool, patented by Mr. Wheeler in 1882, for caulking joints in pipes. A heavy ring slightly larger than the pipe, in two halves joined together embracing the pipe, carries three caulking tools. By sliding the whole on the pipe the tools are driven against the lead in the joints to be caulked.

1646. Machine for making spring-hooks. Presented by Messrs. Newton & Son, 1858. M. 296.

This machine was patented in 1840 by Mr. W. Church, and is for manufacturing spring-hooks for fastening clothing, of a shape patented by him in 1839.

The wire is intermittently advanced into the machine, by a pair of grooved feed rollers, through an elliptical slot, where it is held by pins while a blade cuts off a piece sufficient to form one hook. The pins now bend down the ends of the wire, which curved jaws convert into eyes, but one of these is left with a long end which afterwards forms the spring tongue. A nib bearing on the middle of the wire forces it down a recess in a guide plate while a horizontal ram moved by toggles somewhat flattens it and at the same time sets the spring tongue; on the return movement of this ram the partly finished hook drops out below. These various motions are derived from cams on a main shaft, provided with a flywheel and driven by a belt.

The blank hook thus obtained is completed in the smaller machine, called a beaker. This, has a spindle which can slide longitudinally in its bearings, and which is coupled, by an inclined-plane clutch, to a pulley turning loosely on the former and reciprocated by a band from a spring treadle. The blank hook is placed on the bed, under a pin in the centre of the spindle, and on pushing down the treadle an eccentric pin on the end of spindle bends over the end of the blank and completes the formation of the hook. A stud fixed on the spindle stops its rotation, the pulley continuing to turn, so that the inclined-plane clutch forces back the spindle and withdraws the pins from the hook, which is thus released.

The attached specimens show the stages by which the finished result is obtained.

1647. Model of wheel-moulding machine. (Scale 1 : 4.) Lent by Messrs. Wm. Whittaker & Sons, 1901. M. 3195.

This construction of machine for preparing the sand mould necessary for casting a spur wheel without the aid of a complete wooden pattern was patented by Mr. John Whittaker in 1869, and subsequently improved in detail.

When used for preparing wheels from 3 in. to 5 ft. diameter, a pattern representing two consecutive teeth is secured to an external arm by which it can be lowered into a moulding box resting on a table capable of being accurately rotated by means of a large wormwheel and a worm, which serve as a dividing engine. The interior of the moulding box is rammed up and strickled to a smooth cylindrical surface by a sweep turning on a central post, and the tooth pattern is then placed in position and retained by the arm while sand is rammed into this space. The pattern is then steadily lifted, by the mechanical slide by which it is connected to the arm, and when completely above the mould, the table is, by the dividing arrangement and change wheels, rotated the amount corresponding with the number of teeth required; the tooth pattern is then again lowered and sand rammed up as before, until the mould for the complete series of teeth has been thus prepared. The mould is afterwards finished by the insertion of four or more masses of rammed sand supported on plates and so shaped as to leave spaces corresponding to the rim, arm, and boss, required for the complete wheel.

For moulding the teeth of wheels that are too large for the use of a bottom box, the work is performed in the sand floor of the shop, the table of the machine with its dividing wheel being temporarily bedded in the centre of the mould and the arm with its adjustments bolted to the table, so that the dividing arrangement gives motion to the arm instead of to the box.

In the machine represented the dividing wheel is arranged under the table and boxed in, so that, with its worm, it is protected from the destructive action of the foundry sand. The tooth pattern is held by a pillar and radial arm, carried by a saddle which can be moved along a horizontal bed by a screw. The pillar is adjustable vertically by rack and pinion, and it also allows the arm to be swung to and from the nearly tangential position it occupies while the tooth space is being moulded. The

length of the radial arm is adjustable by a horizontal slide and screw, while the terminal piece which carries the pattern is movable in vertical guides by a rack and pinion.

1648. Moulding machine. Lent by H. Gibbons, Esq., 1893. M. 2535.

This is a machine, patented by Mr. Gibbons in 1880, for securing a straight lift when withdrawing the pattern from the sand, and so preventing damage to the mould by any unintentional movement, while, owing to the facility with which the work can be turned over, "top lifts" are avoided. For repetition work the use of such machines and plate-patterns has greatly reduced the cost of founding.

This machine consists of two turned columns bolted to a bed-plate. On each column is a sliding sleeve, carrying a bearing in which rest the trunnions of an open frame that supports the pattern plate. The weight of the frame is supported by two pitch chains, passing over wheels at the top of the columns and then down to counterbalance weights. The wheels are keyed to a common shaft, provided with a ratchet wheel to prevent running down, and a hand wheel for rotating when lifting the pattern. Clips on the plate hold the box when turned over, and a frictional grip locks the trunnions. In moulding with this machine, the plate is moved up to a convenient height, the moulding box placed on it, clipped, and rammed up. The plate and box are then turned over together and lowered till the box rests on the base, when the clips are loosened and the pattern plate, after being rapped, is lifted off the mould by the machine. The lifting chains are so attached that any slackness of the sleeves in the columns does not influence the lift, the slack being always taken up in the same direction.

WOOD-WORKING MACHINERY.

1649. Model of machine for bending timber. (Scale 1 : 8.) Presented by Capt. Mackinnon, R.N., and J. Draper, Esq., 1863. M. 917.

In this machine a straight piece of timber, after being well steamed, is fixed by one end in a pair of jaws at one extremity of a segment turning upon a pivot. The segment is provided with a powerful lever, having a rope attached to it, with a crab by which it can be turned. A guard-plate behind the timber keeps the tail end from springing away, while the rotation of the segment gradually bends the timber, which is then allowed to dry and set in this curved shape.

1650. Model of circular saw bench. (Scale 1 : 4.) Contributed by Messrs. Samuel Worssam & Co., 1864. M. 953.

The date of the introduction of the circular saw is not known, but in combination with the self-acting carriage it was patented in 1777 by Samuel Miller, of Southampton: it was used there in the manufacture of ships' blocks for H.M. Navy by Walter Taylor. General Sir S. Bentham is credited with bringing the saw, at the end of the 18th century, into a convenient bench form with an adjustable fence.

The saw is formed from a disc of sheet steel; it is clamped by a nut and washer against a flange, provided with a steady pin, solid with the driving shaft. The saw, like the driving pulley, overhangs its bearings, which are underneath and transverse to the bench. Part of the table lifts out to allow of access to the nut for changing saws. The fence or guide is arranged to traverse on a screw in a slot in the table to allow any width to be cut; the fence is adjustable by three set screws at the back.

The advantage of the circular saw is its high cutting speed—6,000 to 7,000 ft. per min.; its disadvantages are its large diameter—about three times the thickness of the piece to be cut—and the waste of wood due to the thickness of the saw necessary for stiffness.

1651. Model of circular saw, with guard. (Scale 1 : 4.) Lent by Messrs. R. Garrett & Sons, 1894. M. 2686.

This circular saw bench is fitted with rollers at each end to facilitate the placing of heavy timber. The usual adjustable fence or guide is fitted, but it has a swivel front, so that timber can be cut on the bevel when desired.

The saw is shown fitted with a guard, introduced in 1884 by Mr. J. B. Lakeman, one of H.M. Inspectors of Factories, to prevent the possibility of a workman falling against a revolving saw, or his being struck by loose pieces of timber carried round by it; it also prevents the discomfort arising from the sawdust being thrown upon the sawyer. The guard consists of a curved metal plate, provided at the front end with a flap that may be thrown back when starting to cut deep stuff. It is substantially made, and is supported by adjustable arms bolted to the table, so arranged that they can be quickly altered in position.

1652. Saw bench with roller feed. Lent by Messrs. Thomas Robinson & Son, 1888. M. 1915.

On this table the timber to be cut is advanced by a mechanical feeding device. A serrated roller, pressed horizontally against the wood, feeds or drives it forward at the required speed; the motion for the roller is taken from the main spindle, reduced by a worm and wormwheel, and communicated to the serrated roller through bevel wheels, a vertical shaft, and a train of spur wheels in the overhanging arm. This arm is pressed against the side of the log by the pull of a weighted chain, and by its swinging attachment can accommodate itself to the varying thicknesses of the log.

1653. Circular saw guard. Presented by Messrs. M. Glover & Co., 1902. M. 3248.

This shows a half-size model of a saw bench fitted with the smallest arrangement of a form of guard, patented in 1898 by Mr. A. W. Glover, for protecting the attendant from accidental contact with the rapidly revolving teeth of the saw.

The whole of the back portion of the saw is shielded by a closely fitting stationary blade, slightly narrower than the cut made by the saw, so that it does not interfere with the passage of the timber; the front of the saw is guarded by a channel-shaped flap under which the wood to be cut is passed. Both of these guards are adjustable to suit saws of different diameters, and the front guard can be set to suit the thickness of wood being cut. The whole arrangement is carried by a vertical post turning in a bracket secured to the bench, so that it can be quickly removed or swung out of the way when not required.

1654. Model of saw-frame for ships' timbers. (Scale 1 : 8.) Presented by Lady Bentham, 1859. Plate XI., No. 1. M. 50.

This represents a machine, patented by Sir S. Bentham in 1793, for sawing timber into curved, bevelled, or winding forms, such as ribs for wooden ships, &c. The timber to be sawn is fixed in a frame which, as it travels along, is moved sideways by means of a pin attached to it travelling in a slot, of the curved form required, in the stationary main framing. The movable frame is mounted upon a second frame, which is capable of rocking

about a horizontal axis, so that the timber may be placed in the right position to be sawn with a bevel, or in a twisted or winding form. Specimens of the work are shown.

1655. Samples of veneer and small blocks. Presented by Lady Bentham, 1859. M. 115–6.

These examples were cut by machines patented by Sir S. Bentham in 1793. Veneers cut from hard woods of ornamental appearance, such as mahogany, rosewood, walnut, bird's-eye maple, &c., are very largely used in the manufacture of furniture, the appearance and surface of the hard wood being obtained by a thin covering of veneer glued on to a foundation of cheaper timber.

1656. Model of reciprocating saw mill. (Scale 1 : 10.) Made by Mons. P. Regnard, 1902. M. 3219.

The application of power to working a number of vertical saw blades stretched in a frame appears to date from the 15th century, and this class of sawing machine is still that most extensively used in Europe for converting lumber into boards and planks. It is not so expeditious as the circular saw mill, but owing to the narrowness of the cuts wastes much less of the timber in sawdust.

The model shows a power frame saw, made by Messrs. F. Arbey & Son, of Paris, in which only one saw blade is used. This blade is carried, in tension, between the overhanging arms of a frame, reciprocated in vertical guides by a connecting rod from a crank pin on shafting driven by belting beneath the floor level. The log to be squared or sawn is gripped at one side by two pairs of claws, actuated by separate screws in two vertical slides or standards which are similarly adjustable across the bed of a carriage, supported on special rails and moved by a pinion engaging with a long rack attached to it. This feeding pinion is rotated continuously, through a train of reduction gearing worked by a belt on speed cones, from the first motion shaft; there is also a friction clutch controlling a quicker and reversed travelling motion for use in running back the carriage. The upper edge of the saw is somewhat in advance of the lower one, so that the teeth shall not drag through the timber in the up or non-cutting stroke; in many frame saws, however, an intermittent feeding motion is given in preference to the continuous arrangement here shown.

In oaken timber for depths of from 12 to 28 in. the rate of feed is from 8 to 4 in. per min., or the area of the surface cut is about 100 sq. in. per minute.

1657. Band saw. Lent by J. Barr, Esq., 1888. M. 1881.

This type of saw is very largely used for straight as well as curved sawing. The saw itself is in the form of an endless band, running at a high velocity over three rubber-covered pulleys, by one of which it is driven. The narrowness of the band enables the attendant to turn the work about so as to cut it in any required direction; the ends of the blade are united by brazing, and the tension is regulated by altering the position of one of the pulleys. The table can be tilted for cutting on the bevel.

1658. Diagrams of wood-working machinery. Presented by Prof. W. F. Exner, 1877. M. 1827.

This series of diagrams shows the various shapes of cutters and methods of fixing them, with particulars of the numbers of cutter-heads, style of feed apparatus, &c. adopted by various English and foreign makers of wood-working machines.

1659. Model of machine for cutting mouldings. (Scale 1 : 8.) Wheatstone Collection, 1876. M. 1553.

This represents a machine for preparing mouldings of the class shown, in which the pattern undulates slightly in two directions. The timber to be worked is secured to a sliding horizontal table, driven by a rack below which is advanced by a pinion worked by spur gear from a winch handle. On the winch shaft are two cams, one of which gives a vertical oscillation to the tool-holder and the other a horizontal oscillation; the holder is held in compound guides secured to the main framing and has a screw for adjusting the depth of the cut. The cutter employed is not shown, but appears to have been a moulding iron the full width of the work; from the worked specimens preserved it appears that the compound motion of the cutter improved the cutting action of the blade.

1660. Circular moulding and dovetailing machine. Lent by Messrs. Thomas Robinson & Son, 1888. M. 2262.

This is a machine with a vertical spindle upon which may be mounted either a tool for cutting mouldings, or a conical tool for cutting dovetails. The table is provided with clamps for holding the boards for the dovetailing, with feed motions for advancing as the cuts are made. For cutting mouldings, an adjustable vertical guide-plate is provided for keeping the work up to the tool as the strip of wood is pushed across the table by hand. Some of the appliances for this machine are shown in an adjacent glass case.

1661. Mortising machine. Contributed by Messrs. M. & J. H. Buck, 1860. M. 391.

This is a machine for cutting the deep grooves or slots that form the most difficult part of the work in preparing the common mortise and tenon joint, so generally used in woodwork. The chisel is controlled by vertical guides and is forced downwards by the action of a foot-lever, the return upward movement being given by a helical spring; the wood to be mortised is held in a vice secured to the machine frame. By means of a screw thread in the top of the tool-holder, it is caused to rotate through one quarter of a circle in the last part of its ascent, and through another quarter in commencing its descent, so that it turns half round after each stroke. Later machines of this type have the frame, &c., of cast iron and the tool moved by a counterweighted hand lever.

1662. Model of copying lathe. (Scale 1 : 5.) Made by MM. Regnard Frères. Received 1892. Plate XI., No. 2. M. 2446.

This represents a lathe for turning articles whose form is irregular and section not circular, such as wheel spokes or gunstocks; the model is shown shaping a table leg.

The machine consists of an ordinary slide-lathe bed carrying two double headstocks, so forming two lathes with parallel axes. The front lathe is driven by a stepped pulley in the usual way, and by an intermediate wheel drives the back lathe in the same direction and at the same speed. A saddle slides on the bed, and carries a slide upon which stand two stout swinging levers connected above by a tie-rod. To the front lever is attached a turning tool, and to the back one a blunt finger. In the back lathe is fixed an iron pattern of the shape desired, and in the front lathe is the work to be turned. A wooden spring is shown which keeps the copying finger in contact with the work, and change wheels and a central guide screw are arranged to feed the saddle along, while a trigger gear is added which releases the feed nut when the saddle has gone far enough. Instead of a turning tool as shown it is usual to employ a rapidly revolving fly-cutter, and to substitute for the copying finger a circular roller of the diameter of the cutter path, by which arrangement a much higher cutting speed is attainable.

1663. Model of wood-carving machine. (Scale 1 : 4.) Presented by J. Clowes, Esq., 1858. M. 138.

This is a machine, patented by Mr. T. B. Jordan in 1845, for carving in wood or other material copies of busts, statuettes, &c. A table, capable of horizontal motion in either direction, is provided to receive both the model or object to be copied, and one or two blocks of wood to be carved. A frame above the table, capable of vertical motion, carries a guide-pin or feeler, with a spherical end, and two headstocks with revolving cutters. By means of the several motions described, the guide-pin is made to travel over the whole surface of the model, with the result that the wood is cut by the cutters to the same shape as the model, but fine lines or any undercutting are done afterwards by hand.

1664. Sand-blast apparatus. Lent by Tilghman's Patent Sand Blast Co., 1893. M. 2541.

The sand-blast consists of a jet of steam or compressed air carrying with it in suspension a quantity of sand or other abrading material, which on account of the high velocity attained by the solid particles cuts away almost any hard substance upon which it is directed. The sand need not be as hard as the material to be cut, for it is found that a sand-blast will work its way through a plate of corundum, and a jet of small shot will depolish sheet glass. The device is used for removing the skin from metal sheets and castings, for sharpening files, and for perforating or depolishing glass or stone, any desired pattern being obtained by shielding the parts that are not to be acted upon by stencil plates of paper or other yielding material.

In the original apparatus introduced by Mr. B. C. Tilghman in 1873, the sand was placed in a hopper connected with a pipe within which a steam or air jet passed. The sand was drawn into the blast by the inductive action of the jet, and then blown out of the end of the pipe against the surface to be acted upon. When steam was used it was found that the moisture caused the sand to clog, and also injured the stencils, so that compressed air was generally used although much more costly than steam.

In 1884 Mr. J. E. Mathewson introduced the arrangement shown, in which, while the velocity is given to the sand by a steam jet, the steam is at once carried off; a jet of dry sand only being projected upon the work. The apparatus consists of a cylindrical vessel with a hopper at the top, which is provided with various covers to suit the work in hand. Those shown are chiefly for supporting bottles while being stencil-marked by this process. The sand-blast passes centrally upwards, discharging itself in the centre of the hopper, but by the exhaustive action of a steam jet in a chamber below, the steam is carried away, and only the sand particles reach the work. The nozzles used are of chilled cast iron, but where a wide thin jet is required, as for file-sharpening, durability is secured by employing three long orifices, the central one to supply the sand, and the two side ones the steam or air. The destructive velocity is not given to the sand until it has left the orifices and been picked up by the two converging steam jets.

LIGHTING APPLIANCES.

Matches.—Probably the earliest method of starting combustion was by friction, as still practised by uncivilised races; a flint and steel is a more expeditious method of obtaining a burning temperature by muscular effort, and, in combination with a tinder box, was the most convenient arrangement known till

the early years of the 19th century (*see* Nos. 1665–6). The discovery of phosphorus in 1670 led to several unsuccessful attempts to use its inflammable properties, previous to the introduction of phosphorus-tipped matches, which came into general use about 1833. In 1827, however, "lights," or friction matches, tipped with chlorate of potash and sulphide of antimony were being sold; the addition of phosphorus was a subsequent modification that reduced the friction necessary for ignition.

Candles and Lamps.—These inventions cannot be ascribed to any definite time, both being the result of successive improvements from the earliest historical times, although the lamp and candle as now used are comparatively modern. It appears that originally the use of artificial light was mainly restricted to religious and other ceremonies, the general illumination of the dwelling-house after dark being a recent institution. The pith rushlight, with oil or tallow, was succeeded by dipped candles with cotton wicks, and these, again, by candles of wax, stearin, &c., moulded by machinery (*see* No. 1670). The plaited wick is an important improvement in the modern candle, rendering snuffing unnecessary; such wicks are now plaited by machinery (*see* No. 1424).

The early lamps consisted of a wick supported in an oil bath, and were candles with a liquid grease. Improved wicks and a chimney that increased the draught gave greater power and steadiness to the light, but the most important development of oil illumination is due to the commercial introduction of mineral oils about 1860.

Gas.—Lighting by means of natural gas appears to have been practised by the Chinese from very early times, but the production of gas from coal was not carried out till towards the end of the 17th century, and then only as a laboratory experiment. In 1803 William Murdock invented the present system of lighting by gas, and with it illuminated a portion of Boulton & Watt's works at Soho. In 1806 his firm supplied a similar plant to a Manchester cotton mill, and in 1808 the Royal Society awarded him the Rumford medal for his important invention. The removal of certain sulphur compounds, which come off with the gas from the retorts, and which when burnt at the jet occasion an injurious and offensive odour, is now known as purifying. The process was introduced between the dates of the Soho and the Manchester lighting, but the now generally used purifiers appear to have been the invention of Samuel Clegg, an assistant at Soho, who afterwards invented the wet gas meter (patented 1815). F. A. Winsor also assisted in introducing this means of illumination, and in 1810 established the Gas Light & Coke Co. By 1816, lighting by gas had become common in London.

In recent years many improvements have been made in gas burners, owing to the discovery that the form and proportion of

the flame largely affect the illuminating power of the jet, but the greatest economy has resulted from the practical introduction by Dr. Auer von Welsbach of a Bunsen burner, in the flame of which is supported a frail mantle of certain oxides which at the temperature obtained are rendered incandescent.

Electricity.—The first electric arc was obtained in 1808 by Davy, who used a primary battery of 2,000 couples and charcoal terminals. Afterwards lamps were introduced, in which the distance between the carbons was regulated by mechanism, but such light was very expensive when the current was maintained by the consumption of zinc and acid. About the year 1850 large magneto-electric machines were introduced, by which an arc lamp could be maintained by the combustion of fuel driving a steam engine; this alteration rendered electric lighting practicable for certain purposes, such as lighthouses, &c., as the cost of the current was greatly reduced. In 1867 was invented the dynamo-electric machine in which a very intense magnetic field is produced without the use of permanent magnets, an improvement of the greatest practical importance, as it so immensely increased the output of the machines (*see* Catalogue, Part I.).

Arc lamps in series and supplied by a high-tension dynamo of about 2,000 volts showed a great saving over lighting by gas where large areas were to be illuminated, but the light was unsuited for many purpose: the application of electricity to general domestic lighting dates from 1878, when the carbon filament lamp was introduced by Edison, Swan, and others. This invention was the result of efforts to obtain a lamp of about the same power as an ordinary gas jet so that it could be similarly applied (*see* No. 1694). In 1897 Prof. W. Nernst patented an incandescent lamp in which a slender rod of magnesia is used and a vacuum is not required (*see* No. 1706), while, more recently, lamps employing filaments of such metals as tantalum, osmium and tungsten, have been introduced (*see* No. 1708). At present the cost of domestic lighting by electricity is greater than by gas, but the absence of combustion is in itself an advantage that in many cases compensates for the difference in cost, and it appears probable that the use of electricity as an illuminating agent will increase, while the demand for gas will be more than maintained by its extended use in heating and cooking.

1665. Tinder box. Presented by the Rev. John Mark, 1898.
Plate XI., No. 3. M. 3012.

In this example the box is of elm, and has two compartments, one for holding the scorched cotton fabric (tinder), and the other for the matches, which are soft wooden sticks tipped with melted sulphur. The much-worn steel is also preserved.

1666. Tinder boxes, flints, and steels. Presented by Lady Bentham, 1859. Plate XI., No. 3. M. 1638.

These are specimens of the tinder box and fittings, for many centuries the most convenient method of obtaining a fire, and one that only slowly fell into disuse after the introduction of phosphorus matches about the year 1828.

The flint was held in the left hand and struck by a piece of steel that fitted over the knuckles of the right. In this way particles of metal, heated to such intensity that they burnt in the air, were torn off, and falling upon finely divided carbon or tinder, prepared by scorching cotton rag, ignited it. This smouldering combustion was increased by blowing until it was sufficient to ignite sulphur, with which the wooden slips, then known as matches, were tipped. The lid served to smother the tinder when a light had been obtained, and was fitted with a socket so as to serve as a candlestick. The tinder was readily ignited if freshly made.

1667. Snap snuffers. Presented by W. S. Julian, Esq., 1906. M. 3469.

This instrument was developed from shears or scissors, it is believed, some time during the 16th century, by adding to one blade a box to retain and extinguish the ill-smelling charred matter cut from the wick of a candle. After the adoption, about 1820, of wicks made by plaiting, which causes the free end to curl over into the outer combustion zone of the flame and be completely burnt, snuffers fell gradually into disuse.

This instrument shown has, in addition, a shutter in the box to prevent the snuffs already taken from dropping out when the snuffers are used again, a device patented in 1776 by Christopher Pinchbeck and somewhat widely used. A spring in the base, worked by a pin in the handle of the snuffers, has a tooth at the end, which engages a cam on the hinge of the shutter when the snuffers are in the open position, and causes the shutter to rise as they close till the tooth slips and the shutter snaps down. There is a second shutter to the box, which can be raised by the finger when the snuffs are to be cleaned out.

1668. Electric taper-lighters. Presented by Mons. P. Jablochkoff, 1877. M. 2900.

The apparatus is contained in a mahogany box, one of whose sides carries a taper, the wick of which is crossed by a platinum wire that can be heated to redness by the passage of a current from a Planté secondary cell contained in the box. The cell can be recharged by a current from a battery of three Daniell's elements.

The apparatus can also be used for firing shots in mines, the cell being stated to be capable of igniting a fuse containing a platinum wire ·05 mm. diam. in a circuit of more than 100 metres of copper wire 1 mm. diam., or of 1,000 metres, 3 mm. diam.

1669. Candle mould. Presented by H. Woolnough, Esq., 1905. Print presented by R. B. Prosser, Esq., 1905. M. 3403.

Mould candles are believed to have been first made by the Sieur de Brez in France in the 15th century and soon after introduced into this country. As beeswax, owing to its great shrinkage, is unsuitable for moulding, the process was confined to tallow and as only the hardest and finest qualities could be used, mould candles were dearer than "dips."

The hand mould shown was in use domestically in Hertfordshire about 1820–40 and is a plain cylinder of tinplate slightly tapered, having a conical lower end with a hole through which the wick is introduced. It is drawn up by a wire with a hooked end, and hung from a bent wire supported in

notches in a funnel or mouthpiece above; a small wooden peg holds the wick below while the tallow is poured round it. A candle made in the mould is shown; there are about 5 of them to the pound.

The engraving, from the "Encyclopédie Méthodique," Paris, 1783, shows the hand-frame and utensils for the manufacture of mould candles on a commercial scale at that period. For spermaceti candles, practically the same method is still pursued at the present day.

1670. Model of candle-moulding machine. (Scale 1 : 2.) Made and presented by Price's Patent Candle Co., 1888. Plate XI., No. 4. M. 1916.

By this machine 96 candles are moulded at each cast, while by the use of cooling water the interval between the casts is minimised. There are two casting trays, from the bottom of which descend vertical candle moulds which are surrounded by a water jacket; the bottom of the moulds pass through the water tank, and each mould is provided with a wick tube that at the upper end acts as a piston, and also forms a mould for the pointed end of the candle. The lower end of the tube is attached to a frame that can be raised or lowered by a rack and pinion at each end. At the bottom of the machine is a creel of bobbins holding the plaited wicks, while at the top are wooden frames which act as clamps, and hold the batch of candles moulded in the preceding cast. These candles secure the upper end of the wick so that it shall remain central in the ensuing cast. The wicks being so held and the piston lowered, the molten wax is run into the trays until it fills the moulds; when solidified the candles in the clamp are cut from the wick and the clamp removed and emptied, a clip at one end when turned releasing the candles instantly. The clamps are then placed in position, and the candles just moulded forced upwards and clamped ready for the next cast.

1671. Gas burner, lighted by electricity. Lent by Messrs. Woodhouse & Rawson, 1887. M. 1729.

This is an arrangement patented in 1872–9 for simultaneously turning on, lighting or extinguishing a large number of gas jets, such as the public lamps of a town, from a central station, so avoiding the work of the lamp-lighter, and the loss through the early lighting necessary from the time occupied on the round.

The arrangement consists of a gas burner with a small tap, which is moved by a lever connected with a rocking plate; on each side of the burner is a horse-shoe electro-magnet, and the magnet excited will pull downwards its end of the rocking plate, so turning the gas on or off. When one side is pulled down the keeper lifts a rod that terminates in a platinum pin on the side of the gas jet; this pin rests on a platinum plate attached to an insulated ring that forms part of the circuit. The service of lamps has two circuits and uses the pipes as a return; the current from one circuit turns on the gas and gives a spark on the breaking of the circuit at the platinum contact; a current through the other circuit turns off the jets.

1672. Wall diagrams of gas works. Lent by the Institution of Civil Engineers, 1894. M. 2915.

These three diagrams, with several others, were prepared in 1894 for a paper by Mr. Charles Hunt, describing the Windsor Street Gas Works at Birmingham.

Fig. 1 shows the plan and general arrangement of the works which are laid down with a view to further extension, and to secure unbroken railway connections. The total storage capacity of the gasholders is 16·5 million cub. ft.

Fig. 2 is a section of the retort house, the position of which is indicated on the general plan. The coal is brought in on an overhead line, 20 ft. above the ground level and 10 ft. above the retort house charging-floor level, and dropped into stores or bunkers. Conveyors or elevators raise it from these into the hoppers which supply the inclined retorts and the charging machinery. The retorts, of which there are two benches, are mostly horizontal, but some are inclined at about 30 deg. The coke produced is either loaded into barges in the adjacent canal basin or into wagons.

Figs. 3 and 4 show a front elevation and longitudinal section of a bed of nine horizontal retorts, 21 in. by 15 in. at the mouth, and 22·25 ft. long. The retorts are ∩-shaped, but rounded on the inside to an oval section to permit of easy withdrawal of the coke. They are charged by means of the Arrol-Foulis hydraulic machines, the coal being pushed forward in small quantities by a succession of strokes automatically shortening from the centre to the mouthpiece of the retort. Each bed of nine retorts is heated at one end of the setting by a single generator, supplied with small coal or breeze, the practice of firing with hot coke from retorts not showing any appreciable saving.

1673. Model of gas works. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., 1896. Plate XI., No. 6. M. 2928.

This model represents a portion of a modern plant for the manufacture of illuminating gas from coal, and was made from information furnished by Sir George Livesey, of the South Metropolitan Gas Co., through Mr. Charles Carpenter.

The bench contains four settings of 10 through-retorts, supported on brick piers and arches, and bound together by buckstaves and tie-bars.

The retorts are heated by gas supplied by a producer, charged from the stage level. This producer is worked under natural draught, and has a closed ashpit, and there is a water seal beneath, through which the clinkers and ashes can be removed as required. Clinkering is done at intervals of from 12 to 24 hours, through the doors provided for the purpose, and occupies about 10 minutes. The air supplied to the producer is heated by passing it through the side walls. The producer-gas, after depositing any solid matter in a dust-pocket, passes through a flue running the whole length of the bench, and thence is distributed in each setting through nostrils or ports formed in the transverse semi-circular flues, where it meets air which has been already heated by its passage through side flues. Combustion then takes place, and the products thereof pass up between the partition walls among the retorts, and down on the outside to transverse bottom flues, which lead the gases to each end of the setting, whence they ascend to the small transverse top flues, and thence to the chimney. The retorts and bricks are of the best Stourbridge or Glenboig clay, and with a few repairs will last between 1,500 and 2,000 working days; the whole of the brickwork and retort within each arch has then to be rebuilt. The retorts are charged and drawn by hand, by the use of the scoops, rakes, &c., shown. The four higher retorts in each setting are reached from a platform, which travels on rails that can also be used by a power-stoking machine if required.

Coal is supplied to the bunkers by a narrow-gauge railway system that commands the whole works, and the bunker has an upper ledge for supplying coal to the travelling platform. The coke when withdrawn from the retorts falls into the vault below, whence, when cold, it is removed in tipping trucks that run on a railway.

The gas from each retort, under a pressure of about ·3 in. of water, is led by a separate pipe to the hydraulic main, which is so shaped as to allow the tar to settle without choking the dip pipes, and there is also an automatic contrivance for draining the main into the tar well. The gas is then cooled by being drawn through vertical annular condensers, which are cooled by the air, the cooling surface being nearly doubled by the internal

air flue. Valves are provided that allow the gas to be taken through either one or both sets of condensers, or straight to the scrubbers. The lighter tars condensed here are also drained into the tar well. The gas then enters the exhauster or rotary pump, which is driven by a steam engine that has its throttle valve controlled by a miniature gasholder, which rises and falls with the fluctuations of pressure in the retort house gas main, so that the speed of the exhauster changes in a way that corrects any variation in the rate at which the gas is evolved from the coal.

A bench of retorts as shown is capable of treating 52 tons of coal in 24 hours, yielding 530,000 cub. ft. of purified gas, corrected to a pressure of 30 in. bar. and 60 deg. F.

1674. Model of gas purifying house. (Scale 1 : 24.) Made by B. L. F. Potts, Esq., 1898. Plate XI., No. 6. M. 3037.

This shows the apparatus by which the gas, prepared in the plant represented in the previous model, is purified so as to be fit for consumption. The chief impurities removed are tar, ammonia, sulphur compounds, and carbon dioxide.

The cooled but crude gas entering the plant represented is led to one of a pair of Livesey washers, consisting of a rectangular chamber made of cast-iron plates and containing a large number of horizontal tubes perforated below so that the gas forced into the tubes is delivered beneath the water in which they are immersed; the gas, in bubbling up through the surrounding water, parts with much of its tar and ammonia. These washers are worked alternately, and the purifying water is continuously admitted into the working one through the siphon pipes shown.

The gas now passes to the scrubber towers, which are built up of cast-iron flanged plates and filled with boards (9 in. by ·25 in.), stacked on edge. At the top of each scrubber is a sprinkling pipe, which, by the reaction of its water-jets, is kept revolving in the same way as a Barker's mill; two external discs connected with the sprinkler show if the apparatus is working correctly. In these towers the remaining tar and more ammonia are removed.

The gas now passes to a pair of Kirkham's washers, in which further washing with water is performed by the gas being exposed to a large amount of wet and moving surface. The machine consists of a series of chambers through which passes a horizontal revolving shaft fitted with discs of iron plate ·125 in. thick; the chambers are nearly half filled with water and are connected in series, so that the gas, which flows through the apparatus in the reverse direction to the water, is treated with cleaner water as its purification progresses. The gas enters the washer at one end, and passes from the centre to the circumference between one set of discs, then back to the centre of the next set of discs, and on through a central orifice in a fixed diaphragm to the next double set of discs, and so on, the successive sets of discs being continuously washed in their respective water compartments and there leaving their collected impurities. The washers are driven by a steam engine and gearing, and the supply of purifying water is introduced by a siphon pipe, communication between the successive chambers being provided by means of the external pipes shown.

The completely washed gas is now passed to the lime purifiers in which the carbon dioxide and some of the sulphur compounds are removed by allowing the gas to pass through powdered slaked lime. The lime required for this purpose is lifted to the upper floor of the purifying house and there hydrated, or slaked; it is then discharged through canvas tubes into the purifiers below. These consist of shallow chambers fitted with covers that can be lifted by an overhead travelling crane, and which when lowered upon the chambers make a water-sealed joint. Inside, the chamber is divided into two by a central wall, and each compartment is fitted with perforated floors on which the lime rests; the gas passes up through one set of floors and down through the other, thus making a double passage, while the arrangement avoids the use of any pipe joint in the removable cover.

When the lime becomes saturated, the lid of the purifier is removed and the lime discharged through pipes into side-tipping trucks running on a railway below. Exposure to the air will, however, restore to the lime much of its purifying properties, so that it is repeatedly used before it becomes so impure as to be quite unserviceable,

From these purifiers the gas passes to a similar arrangement, in which, in place of lime, oxide of iron is used, by which material the sulphur compounds are chiefly removed. In the plant shown there are four lime purifiers, three of which will always be in use, while of the two oxide purifiers one only will be working at a time. After continued use the oxide becomes impure, but it soon recovers some of its powers upon being exposed to the air on the open floors shown; ultimately, however, it gets so full of sulphur as to be unfit for purifying work, and is then sent to the sulphuric acid makers, who use it as a source of sulphur and reconvert it into oxide of iron.

The purified gas is now delivered into the gasholder and thence into the mains.

1675. Model of column-guided gasholder. (Scale 1 : 48.) Made in the Museum from drawings supplied by Messrs. Ashmore, Benson, Pease & Co., Ltd., 1907. Plate XI., No. 5. M. 3432.

Reservoirs for storing large volumes of gas became necessary, industrially, on the introduction in 1803 of coal-gas manufacture, in order that a fluctuating consumption might be met by regular production from a relatively small plant; it is in this direction that such reservoirs have reached their highest development.

The gasholder took its rise from a laboratory apparatus consisting of a counterbalanced copper bell suspended in a tank filled with water, invented by Lavoisier in 1782 for measuring gases; hence the name "gasometer." As first constructed for coal-gas, holders were rectangular in plan, and it was not till 1816 that the circular form was introduced; they were heavily stayed on the interior in order to resist internal pressure, and it was not till after 1819 that it was gradually realised that the stresses due to the pressure of the gas might be neglected if the vessel were made structurally able to retain its form when grounded. This only involves top and bottom curbs, stiffeners for the sides, and trusses for the crown; even the latter may be dispensed with if a timber framing be provided for the crown to rest on when grounded. Diminution in weight has led to the disuse of the counterbalances formerly used, except where retained to alter the pressure or to keep it constant as the displacement of the holder varies.

Although the greatest capacity for a given surface in a cylinder closed at one end is obtained when the height equals half the diameter, this proportion is rarely adhered to in practice on account of exigencies of space or cost of land.

Increase in the depth of the tank proportional to the increased height would be necessary if the holder were not divided into 1 to 5 lifts telescoping one into the other. This method, which was introduced in 1824 by Mr. Tait at Mile End Gas Works, is also used for increasing the capacity of existing holders. The bottom edge of the top lift is bent to form an annular trough which comes up full of water from the tank and picks up the next lift, which is provided with a corresponding edge, thus forming a water seal.

The construction of tanks proved at first a serious difficulty. Wooden vats, brickwork and masonry, with or without a backing of puddled clay, natural rock, concrete, cast iron, wrought iron, and steel have all been used. In the three latter cases the construction may be wholly or partially above ground, saving cost of excavation; to this end also in large tanks nothing but an annular trench is dug, or the ground may be left as a frustum of a cone. It has been proposed to use the central portion as a store.

The holder shown was erected in 1881 at Great Harwood for the Accrington Gas Co.; it has two lifts, the upper being 118 ft. diam. and the lower 120 ft. diam., both 27 ft. deep. The tank is 122 ft. diam. and

27 ft. deep. The material is wrought iron in sheets ·2 in. thick, except the circumferential crown plates and the top and bottom side plates of each lift, which are ·25 in. thick. On the crown the plates are laid herring-bone fashion to obviate waste in cutting to segmental outlines. The whole is coated with gas tar to prevent leakage. The top curb is of 5 in. by 4 in. by ·5 in. angle, the stiffeners of 6 in. by 3 in. by ·5 in. channel, and the bottom curb 5 in. by 4 in. by ·62 in. angle. The troughs or cups are 18 in. deep by 10 in. wide. The crown is supported, when grounded, on a timber framing composed of 6 in. square posts with ·75 in. diagonal rods supporting 11 in. by 3 in. beams.

The capacity of the holder is upwards of 600,000 cub. ft. or equal to the production of a plant such as Nos. 1673–4 during 24 hours, that being the usual allowance in reserve.

1676. Model of cable-guided gasholder. (Scale 1 : 48.) Made in the Museum from drawings supplied by Messrs. Ashmore, Benson, Pease & Co., Ltd., 1906. M. 3431.

Various means have been employed for guiding a gasholder and supporting it against wind pressure. The earliest method, only applicable to very small sizes, was by a central chain over a pulley on an overhanging beam; another was by a central tube which accommodated the counter-balances. By far the most generally used method is by columns, connected by cast or wrought iron girders (*see* No. 1675) often, as the size increased, with intermediate diagonal bracing. The heavy cost of this ironwork and the resulting foundations has led to other means being tried, *e.g.*, helical guides were patented in 1887 by Messrs. W. Gadd & W. F. Mason.

The model, however, shows a method for guiding by wire ropes without any other support, patented in 1888 by Mr. E. L. Pease and carried out at Haslingden the following year; three or more wire ropes fixed to the tank top pass round pulleys placed on the bottom curb of the holder and are then guided over the crown to a point of attachment on the tank at least one-third of the circumference away. In the case of a multiple lift the cables pass round pulleys on the bottom curbs of both lifts, generally on alternate sides, and then over the top.

Another plan, as shown in the model, is to have a separate series of cables for each lift. Each cable of the lower lift is attached to the bottom curb, brought up to the edge of the tank, guided round one-third of the circumference and guided by a pulley on the tank to a fixed point at the top of the lift. The upper lift is similarly treated, except that the cable passes straight over the crown.

To increase the controlling power of the cable on any given lift, Mr. Pease, in 1895, patented the application of the pulley block principle, passing the rope two or three times up and down the particular lift before passing to the next.

The holder shown was erected in 1890 at Newburn Steel Works for a water-gas installation. It has two lifts, the upper being 43 ft. diam. by 17·25 ft. deep with 2·5 ft. rise of crown and the lower one 45·5 ft. by 17 ft. deep; the material is wrought iron in sheets ·08 in. thick, except the sheets under the pulleys near the circumference of the crown, which are ·18 in. thick, and the top and bottom sheets of both lifts which are ·2 in., while the cup sheets are ·25 in. thick. The top curb is of 3 by 3 by ·37 in. angle and the bottom of 3 by 2·5 by ·5 in. angle, the stiffeners are 3 by 3 by ·37 in. angles inside, while the paths for the rollers are 4·37 by 2 by ·37 in. channel. The cups are 16 in. deep by 9·25 in wide. The crown is supported, when grounded, by 12 radial trusses of 4 by ·5 in. flat bars, 1 in. diam. struts and ·75 in. tie-rods, the segmental spaces are panelled with flats or angles: besides these there are 6 main tension rods 1 in. diam. tying the top curb to a column 6 ft. deep in the centre of the crown.

The tank is of wrought iron 47 ft. diam. by 17·75 ft. deep, partly buried in the ground and built up of plates varying from ·31 in. to ·19 in. thick.

The capacity of the holder is upwards of 50,000 cub. ft.

1677. Model of machine for charging and drawing gas retorts. (Scale 1 : 12.) Contributed by J. Somerville, Esq., 1876. M. 1539.

This machine was patented in 1871 by Messrs. Somerville & Robinson, and in the model is arranged for simultaneously operating on three retorts. The object is to place the coal into the hot retorts, and afterwards to withdraw the glowing coke from the retort, on the completion of the process, by steam power.

The whole machine is mounted on a four-wheeled frame that travels on rails, and all the movements, including the travelling, are derived from a vertical boiler driving two vertical steam cylinders. The discharging of the three retorts is done by three long hoes carried in a frame, which is forced forward by a pitch chain; the blade of each hoe is hinged to the shaft, and by a side lever its inclination can be altered, so that it enters with its surface horizontal, and on reaching the extremity of its path is turned vertically; the whole frame is then moved backwards, so that the three hoes are withdrawn, bringing with them the contents of the retorts. To recharge these three retorts the machine is moved along about two feet, and the coal which is contained in a hopper at the top of the machine is by three horizontal open cylinders measured off, and by the further rotation of the cylinders is dropped into inclined shoots that deliver the charges into horizontal charging scoops. These three scoops are by pitch chain carried forward with their frame, and when completely in the retorts are rotated, so depositing their coal on the bottom of the retorts, leaving themselves free for withdrawal. The control of the various motions is given by clutches, actuated by levers close to the engine.

1678. Model of oil-gas apparatus. (Scale 1 : 4.) Lent by Messrs. E. A. Mansfield & Co., 1894. M. 2693.

Oil-gas is a mixture of various hydrocarbons and is obtained by decomposing oil, grease, &c., in a retort maintained at a bright red temperature or about 930 deg. C. The decomposition of the vapours results in the delivery of a fixed gas which possesses great lighting and heating properties and can be stored in a gasholder.

The model shows the complete producer and the simple washing appliance used, while the diagrams represent a complete installation. The producer consists of a vertical cast-iron cylinder lined with firebrick, placed above a small furnace, beneath which is an ashpit with a water bottom. The retort in which the oil is decomposed hangs by a flange through the cover of the producer. The retort is closed by a cast-iron pipe which makes the connection with the washing arrangements,—all difficulty with the joints being avoided by providing a channel containing molten lead above the retort and a similar joint with water for the other extremity. The gas after leaving the retort passes downwards through the vertical pipe into the water at the hydraulic box, where the tar and other condensable products are separated, and then on to the gasholder for use as required. The oil is automatically fed into the retort by a siphon pipe which reduces the supply of oil when the gas pressure rises. In front of the producer is a hole through which the retort can be inspected and its temperature estimated, while the chimney for the furnace heating the retort is arranged at the back. A closed furnace is used so that the rate of combustion can be completely controlled by a damper in the ashpit. The vertical delivery pipe passes to the bottom of the washing box, the gas from it ascending through the water and being carried off by a pipe above the surface.

1679. Gas governor. Lent by Messrs. James Stott & Co., 1890. M. 2337.

This apparatus, which is inserted on the consumer's side of the meter, is for the purpose of securing a uniform and economical pressure upon the

gas supplying a building irrespective of the number of jets in use. The spindle, whose motion regulates the opening of a double beat valve, is attached to the centre of an inverted metal cup floating in a circular trough of mercury. The gas from the mains enters through this valve and fills the cavity of the float passing out to the burners, under a pressure which is just sufficient to keep the float suspended and the valve open to the requisite extent. To increase the pressure at the burners, additional weight can be added to the float.

1680. Douglass gas burner and pilot light. Lent by F. H. Vigne, Esq., 1891. M. 2387–8.

This burner consists of an ordinary Argand ring, around the exterior of which is arranged a series of hemispherical deflecting plates, the lower part of the glass chimney acting as the outermost deflector. By this means the flame is contracted above the perforated ring and the up currents of air are deflected on to the surface of the flame, so as to ensure complete combustion and augment the intensity of the light.

The pilot light at the side is an arrangement for lighting the gas burner. When the burner is in use this light is extinguished, and relights when the burner is being turned out; but, if it is required to extinguish the flashlight also, the small lever is raised, this change allowing the gas to be turned off completely.

1681. Welsbach gas burner. Lent by the Incandescent Gas Light Co., 1891. M. 2386.

This is an early form of the incandescent burner now so generally used. The arrangement was introduced by Dr. Auer von Welsbach in 1885, and on account of its great lighting power in proportion to the gas consumption soon commanded attention.

The gas is burnt in an air-gas or Bunsen burner, whereby a higher temperature is maintained than is found in an ordinary burner, owing to the smaller volume of the flame in which the combustion is completed. Into this flame certain light solids which possess the property of becoming intensely incandescent at the temperature attained are introduced, by placing in the flame a gauze mantle; this usually contains about 98 per cent. of thorium oxide and 2 per cent. of cerium oxide. Owing to the fragile nature of the mantles, they are sprayed with a varnish before being sent out, but this resinous matter quickly disappears upon the mantle being ignited. The mantle is shown connected with and supported by an external wire standard, but the central clay rod now used is a much better arrangement.

1682. Incandescent mantle specimens. Presented by the Ramie Co., Ltd., 1907. M. 3501.

These specimens illustrate the manufacture of incandescent mantles from ramie fibre, a material that was first adopted for this purpose, instead of cotton, in 1898. The fibre is coarser, the shrinkage less, while the light emitted does not fall off so rapidly with ramie as with cotton.

Ramie grass is boiled with caustic soda to extract gummy matter, and the fibre is carded, twisted, and doubled to obtain yarn much as in cotton manufacture. From this a tubular web is obtained on a knitting machine. This is cut into lengths, the end hemmed and gathered up by an asbestos thread which also forms the loop for the support or crutch. The web is then dipped into an impregnating solution of 98·5 to 99 per cent. thorium nitrate and 1·5 to 1·0 per cent. cerium nitrate. Nearly all the light-emissive properties are due to the latter. Both thoria and ceria are extracted from monazite sands found in Brazil, North and South Carolina, and South Nigeria; thoria also comes from thorianite of Ceylon.

After dipping, the mantle is wrung out, stretched on a shaping cone, and allowed to dry. The fibre is burnt out in a delicate operation involving great shrinkage. The mantle is then very fragile and is made fit for transit by dipping in a solution of collodion.

1683. Gas burners and mantles. Presented by the Welsbach Incandescent Gas Light Co., 1908. M. 3539.

The two burners, shown in section, are of the form patented in 1897 by M. Ottmar Kern. The Bunsen tube is contracted to give greater induced current effect and delivers the mixed air and gas into a conical chamber perforated with vertical outlet slits and with a solid apex. This is surrounded by a casing which directs the gas, in the case of the upright burner, through helical teeth on the edge of a disc. In the case of the inverted burner, the solid apex is inside the perforated cone and no disc is needed. It is claimed that a certain amount of heat regeneration is thus obtained giving a higher temperature of incandescence to the mantle. This inverted burner has in addition the gas adjusting nozzle patented in 1907 by C. G. Brett and F. Henneberger. A plug with a conical end which enters the nozzle is wedged down by a set screw acting on an incline on the plug.

Knitted fabrics and the finished mantles for the largest (for lighthouse purposes) and smallest (16 c.p., ·75 cub. ft.) sizes made are also shown.

1684. Comet lamp. Lent by Messrs. Sinclair & Co., 1891. M. 2414.

The light from this lamp is caused by the combustion of a jet of mineral oil vapour, a large flame being obtained suitable for illuminating works at night. A copper cylinder is fitted with an air pump and pressure gauge, and also a valve for regulating the supply of oil to the burner, which valve is provided with a tube reaching almost to the bottom of the cylinder. The burner consists of a wrought-iron tube, the upper part of which is coiled, while the lower part is furnished with a small orifice by which the oil vapour issues. It is surrounded by a wrought-iron casing, in the side of which is a sliding door to regulate the supply of air. The cylinder is filled with oil to within 4 in. of the top, and the air pressure then increased by the pump till about 25 lbs. is registered on the gauge. When the oil valve is opened the compressed air drives the oil up the internal pipe and through the heating coil to the nozzle. The flame keeps the coil of the burner hot and so vaporises the contained oil, but when starting, a ball of cotton waste, soaked in paraffin and ignited, is used to heat the coil. When stopping, after the oil supply is closed, a small valve is opened, which allows some of the compressed air from the top of the cylinder to blow through the burner, and so remove any collected deposit. This size lamp is intended for the consumption of ordinary lamp petroleum, of which it holds three gallons. When charged it is stated to give a light of 500 c.p. for 3 hours, but requires the air pressure restoring twice in this interval.

1685. Holmes's electric lamp for lighthouses. Lent by the Corporation of the Trinity House, 1879. M. 1468.

This is the first electric lamp used for lighthouse purposes, and for 13 years was regularly employed in one of the lanterns at the South Foreland. It was invented in 1862 by Prof. F. H. Holmes, who had in 1858 introduced the powerful magneto-electric machine by which the current was supplied. It is a focussing lamp driven by gravity; the two holders slide in vertical tubes and have their motion controlled by catgut bands, passing over pulleys that reduce the movement to one-fourth of that of the catgut. The ends of the bands are wound in opposite directions round two drums whose diameters are proportioned to the rate of consumption of the two carbons; the motion of the drum axle is controlled by a star-wheel which is checked by a finger,

pulled down by an electro-magnet and upwards by a spring. When the current falls below a certain amount the lever rises high enough to clear the star-wheel, the distance between the arms of the star-wheel gives a feed of ·005 in., and if this closing sufficiently strengthens the arc the lever will be pulled down and further feeding will be stopped.

The fixed end of the band controlling the upper carbon is connected with a lever that is attached to the armature of a horse-shoe electro-magnet, so that when starting the lamp the carbons then in contact will be separated by a considerable distance so as to start the arc. The fixed end of the cord of the lower carbon-holder is attached to a spindle by which it can be wound in, so as to place the arc accurately at any desired height, which the apparatus will then maintain. The mechanism is completely boxed in, but five external buttons give control of the various adjustments.

1686. Experimental Jablochkoff electric candles. Presented by Mons. P. Jablochkoff, 1877. M. 2899.

This form of electric lamp was introduced by Paul Jablochkoff in 1876, and on account of its extreme simplicity was very extensively adopted.

Two holders are shown, each clamping a carbon enclosed in a porcelain tube. The other carbon in each case was placed outside the tube and parallel with it, the tube preventing the arc from creeping down between the carbons except as the tube was destroyed. The positive carbon was in the tube and the negative outside; to allow for the difference in their rate of consumption the external carbon was only one-half of the section of the internal one. The irregular destruction of the tube is a defect in the arrangement that was avoided in the later plan (*see* No. 1687).

1687. Jablochkoff electric candles and holders. Presented by the Jablochkoff Electric Lighting Co., 1887. M. 2241–2.

The two carbons, each of ·16 in. diam., are placed parallel separated only by a thin stick of porcelain; the lower ends of the carbons have sheet brass terminals by which a good contact can be made, by simple spring terminals, to the holders. At the top of the carbons the circuit is completed by a carbon paste, which, when the current is sent through, is heated and volatilised, the extremities of the carbons at the same time being so heated that sufficient vapour is given off to maintain the arc across the kaolin, which is, however, slowly volatilised as the carbons burn away. The difficulty due to the unequal consumption of the carbons is overcome by using an alternating current, but at first carbons of different section were employed for this purpose. To reduce the oxidation of the carbons and also to increase their conductivity, they are plated with copper; by this means a life of about 1·5 to 2 hours is obtained.

To give light for a longer period, the form of holder shown is used, in which several candles are supported, to be lighted successively. The central terminal is on the return circuit and each of the others on a separate wire, which is switched in by an attendant as a candle burns out. Automatic arrangements for this purpose were also used.

The Jablochkoff candle and the Gramme machine were the two inventions that led to the first extensive application of electric lighting on an industrial scale.

1688. Arc lamp. Lent by Killingworth W. Hedges, Esq., 1902. M. 3234.

The employment of inclined guides, down which the carbons moved by gravity, as they were consumed, while resting against a piece of refractory material to establish the arc, was patented in 1846 by Mr. W. E. Staite, but the practical introduction of the arrangement took place much later, when the commercial application of the electric light was commenced. This arrangement was re-invented by M. J. Rapieff in 1878, and in 1879 by

Mr. Hedges, who introduced the modification shown, which was in use at the Liverpool Docks.

The carbons slide down metal troughs inclining towards each other at a slope of 40 deg., but the trough which carries the positive carbon is provided also with a small carbon converging to its point, so that although being consumed it acts as a stop or abutment. The negative carbon in the other trough is prevented from sliding downward by an adjustable platinum stop pressing against its conical end; this trough or holder, however, hangs from links by which it can swing horizontally under the attraction of an electro-magnet, in the main circuit, which thus strikes the arc when starting and also regulates it. To maintain good contact and uniform resistance between the carbons and their troughs, hinged fingers are added which rest on the tops of the carbons.

1689. Arc lamp. Lent by Killingworth W. Hedges, Esq., 1902. M. 3233.

This early form of gravity-fed lamp was patented in 1879 by Mr. R. E. B. Crompton. In it the lower carbon is almost stationary, having only the slight motion necessary for striking the arc, and this is given by the downward pull of an electro-magnet whose coils are in series with the carbons. The upper carbon is carried by a rod provided with rack teeth engaging with a train of wheels which it drives by its weight. This train terminates in a brake wheel upon which a lever is pressed by an adjustable spring, but released by the pull of an electro-magnet at the top of the lamp; the coils of this magnet form a shunt circuit of high resistance, so that, as the resistance of the arc increases, through the consumption of the carbons, the greater current through the shunt coil releases the brake and allows the upper carbon to slowly descend.

1690. Arc lamp. Lent by Messrs. Ernest Scott & Mountain, 1890. M. 2355.

This lamp is fed by the descent of the upper carbon-holder under gravity, when the frictional support derived from the action of the core of a coil in series with the arc is less than the weight. The upper carbon-holder is provided with a long rack above, gearing with which is a pinion carried in a slide capable of motion in vertical guides. On the pinion shaft is a pair of friction sheaves each half embraced by a chain, one end of each chain being attached to the frame of the lamp and the other end to the core of a vertical coil. When the current is started this core is drawn upwards lifting the pinion and its slide by the chains, and afterwards slowly lowering these parts as the arc tends to lengthen and reduce the strength of the current. After the pinion and slide have descended so far that the block is at the bottom of its guide the further descent of the core slackens the chains round the friction sheaves, so allowing the pinion to rotate and the rack to fall until the strengthening of the current again tightens the chains. By two side levers the core is connected with an air dash-pot by which the action of the coil is steadied.

The lamp shown is for working in parallel, requiring 10 ampères at 65 volts, but when arranged for series working, 50 volts only are necessary.

1691. Brush's arc lamp. Lent by the Brush Electrical Engineering Co., 1891. M. 2402.

In this lamp there are two pairs of carbons, so arranged that when one pair is burnt out the arc is formed between the second pair. The feed is obtained by gravity, the upper or positive carbons only being moved, and to check their descent the holders are made hollow and nearly filled with dilute glycerine, a plunger suspended from the top of each holder casing converting the holders into dash-pots. The main current passes round two large coils, causing them to magnetise and raise a **U**-shaped core, which by means of a lever raises a clutch acting on the holders and so separates the carbons.

The clutch is in the form of a washer loosely fitting on each holder, but when the lever rises it tilts these washers, causing them to jam on the holders and so lift the carbons. As one washer is given more play than the other, the carbons are not lifted at exactly the same instant and the arc is formed only between the pair last separated, until these are consumed.

The regulation is effected by a high resistance winding round the two large coils. The current through it is shunted from the arc, and passing in the opposite direction to the main current reduces the magnetic action as the arc resistance increases, so allowing the holder to slide through the clutch until the arc has recovered its normal intensity. A small glycerine dash-pot on the side of the lamp steadies the action of the clutches.

There is an automatic magnetic cut-out arranged on a shunt from the carbons, so that when the arc resistance is too high, through the carbons being burnt out, the lamp is short-circuited, so fitting these lamps for working in series. The lamp requires a current of 10 ampères at 50 volts.

1692. Planet arc lamp. Lent by the Planet Electrical Engineering Co., 1890. M. 2353.

In this lamp the length of the arc is controlled by a small electric motor which winds the upper carbon down or up as the resistance of the arc varies from the normal amount.

The upper carbon-holder has a rack into which engages a pinion connected by worm gear with the spindle of the small vertical motor. The action of the motor is controlled by a shunt coil of fine wire connecting the carbons so that a high arc resistance will cause a strong current through this shunt coil and *vice versâ*. The core of this coil attracts a vibrating arm against the pull of a spring; and unless the two balance, which is the case with the normal arc, contact is made by the arm, and in such a way as to pass a current through the armature of the motor which will cause motion in the direction necessary to correct the irregularity. When the lamp is not burning the upper carbon falls by gravity, owing to the gear being disengaged through the yoke piece of the field magnets of the motor spinning back and carrying the worm on the armature shaft with it.

The exact method in which the motor is controlled is shown in an adjacent diagram. When the arm M makes contact with the screw U a current passes through the armature in the direction of the red arrow, being shunted from the blue coils of the field magnets; similarly when M makes contact with L the current through the armature follows the blue arrow and is shunted from the red coils. In both cases the polarity of the magnets remains the same, but the direction of the current through the armature is reversed. When M is in the mid position there is no current through the armature.

1693. Jandus enclosed arc lamp. Lent by Messrs. Drake & Gorham, 1905. M. 3385.

The example shown is a lamp patented by Mr. W. Jandus in 1894–5, in which the arc is enclosed in a small opalescent cylinder placed inside a large outer globe, also opalescent. The lower or negative carbon is fixed and its holder carries a small cylinder, which is airtight at the bottom and covered at the top by a metal cap through which the positive carbon just passes. The upper end of the large globe is made airtight by clamping it between asbestos washers, while an inverted metal saucer, pressed by a coiled spring against the lower end, allows the gases to escape when the pressure inside rises sufficiently.

The controlling mechanism consists of a series coil partly surrounded by an iron sheathing, the upper portion of which forms a pole piece. To the bottom of an armature fitting into the lower end of the coil, a hollow piston is attached which closely fits its surrounding case and acts as a dash-pot. When the armature is raised by the passage of a current through the coil,

the inner face of the piston, being tapered, so engages with clutch rings, placed in radial slots in the armature, as to press them against the loosely fitting positive carbon which they grip and raise with them. In this way the arc is struck; when it becomes too long its increased resistance diminishes the current through the coil and the armature descends. The clutch rings then come into contact with a fixed tube and release the carbon rod which feeds downward, passing through a group of centring contact rings. A steadying resistance wound in a horizontal spiral and covered with asbestos is also included in the circuit.

In enclosed arc lamps one pair of carbons will burn from 150 to 200 hours, and their ends do not become tapered but remain nearly flat. A longer arc is obtained, and a greater voltage required than in an open arc, whilst the distribution of light is more uniform.

The lamp shown is designed for simple parallel working on a continuous current circuit of about 100 volts, and takes a current of 5 ampères.

1694. Edison's original incandescent electric lamp. Presented by T. A. Edison. Esq., 1880. M. 1488.

This is one of the early experimental lamps of Mr. Edison. The filament, probably of carbonised cane fibre, is carried by platinum terminals fused into a thin glass stopper which was afterwards fused into the neck of the globe. The globe was exhausted through a small tube at the opposite end, which was then fused over. The lamp gave a light of 13 candles and had a life of 1,390 hours.

1695. Early forms of Swan's incandescent lamps. Presented by J. S. Beeman, Esq., 1897. M. 2990.

These were made under Sir J. W. Swan's patents of 1880, &c., and show the constructions adopted till 1882.

In these the platinum terminals are supported in fine glass tubes and the filament is secured by carbon wedges; the external contacts are made by brass springs set in plaster of Paris. The lamp-holder is a wooden socket with a gas nipple thread and is provided with terminal screws.

This is similar to the above, but the platinum terminals are prolonged as stout metal tubes into which the thickened ends of the filament are held by an arrangement resembling a crayon-holder; the latter are further supported by a central glass stem.

1696. Early lamps by the Swan Electric Light Co. Presented by J. S. Beeman, Esq., 1897. M. 2992.

In these lamps, made in 1882, the filaments are attached by carbon cement to the platinum terminals, which are themselves held in a glass rod that is fused into the end of the bulb; the external contacts are platinum loops. In one example the carbon filament is of ribbon form, to give increased radiating surface, while to provide for the greater current required the platinum terminals are in duplicate.

1697. Lane-Fox's incandescent electric lamps. Presented by St. G. Lane-Fox, Esq., 1881, and J. S. Beeman, Esq., 1897. M. 1513 & 2991.

Mr. Lane-Fox was an early worker in the subject of electric lighting by incandescence. His lamps had usually a filament of prepared vegetable fibre connected with platinum terminals fused into a two-legged glass tube that was fused into the neck of the lamp globe. Mercury was introduced into the tubes, and into it dipped the large copper terminal wires, which were then sealed in with marine glue and cement. The resistance was regulated by "flashing" (*see* No. 1701), and the exhaustion of the lamp was completed while the filament was incandescent.

One example is an early experimental lamp, while the other shows the lamp as manufactured in 1882. In the commercial specimen the mercury is retained in place by cotton wool and the end of the filament-holder is plugged with plaster of Paris, through all of which the copper terminals extend; the filament-holder forms an independent plug which is fused into the neck of the globe. The lamp is stated to have been of 20 c.p. with 39 volts, and to have had a resistance of 15·5 ohms hot and 28 when cold.

1698. Brougham & Ormiston's incandescent lamps. Presented by the British Electric Light Co., 1882, and J. S. Beeman, Esq., 1897. M. 1540 & 2994.

In these lamps the terminals are secured to an independent holder, which is fused into the neck of the globe and is provided with a central tube through which the exhaustion is performed. The terminals are of copper-plated wire and the ends of the filament are attached by carbon collars.

The lamp-holder has an ebonite plug carrying the binding screws and is provided with a split socket and tightening collar by which the stem of the bulb is secured. These lamps were commercially manufactured in 1884, and the box shows the system of packing employed in forwarding.

1699. Early lamps by the Woodhouse & Rawson Co. Presented by J. S. Beeman, Esq., 1897. M. 2993.

The filament and its platinum terminals are inserted through the flattened neck of the lamp, which is then fused round the wires.

1700. Early lamp-holders. Presented by J. S. Beeman, Esq., 1897. M. 2997.

This is a series of holders generally designed for fitting lamps to existing gas chandeliers as patented by Sir J. W. Swan in 1881. The holders are for lamps with loop terminals, contact being ensured by various arrangements of springs, which also maintain the lamp in position.

1701. Specimens illustrating the manufacture of electric incandescent lamps. Lent by the Edison & Swan United Electric Light Co., 1890. M. 2359.

The complete lamp consists of a fine conducting filament of carbon with platinum terminals sealed into a highly exhausted glass globe. The great resistance of the carbon causes it to become white hot when placed in an electric circuit, while the absence of air prevents its destruction by combustion. The following is an outline of an early process of manufacture in America :—

Bulbs.—These are blown from a glass tube about 1 in. diam., one end of the tube being drawn down and fused to a small tube which is afterwards used in exhausting and sealing the bulb. The other end of the 1-in. tube is cut off at about 1·5 in. from the bulb, and will form the stem of the lamp. This is partly closed by flattening and the prepared filament inserted. The stem of the bulb is then completely closed in, clipped off, and fused round the platinum terminals. The air in the globe is afterwards removed by a mercury pump until a very high vacuum is obtained, when the bulb is closed by fusing off the fine end.

Filaments.—Ordinary sewing cotton, or in some cases silk, is steeped in sulphuric or nitric acid, so as to leave only the cellulose. It is then wound round a rectangular block of carbon and firmly lashed by a winding of plain cotton crossing it at right angles. The coil at one end is cut through, thus leaving the winding in the form of a number of loops which are free to contract. The block with its wrappings is placed in a crucible and tightly packed round with plumbago until all oxygen is excluded, when the crucible is fired for about 12 hours. After cooling, it is found that the cellulose loops, which have considerably shortened, are converted into conducting filaments of carbon.

Flashing.—This process greatly strengthens and improves the filaments and brings them to a standard resistance. It consists in passing a current for a second or two through the filament while it is in an atmosphere of carburetted hydrogen, or it may be in a liquid hydro-carbon; this decomposes the hydro-carbon, the carbon being deposited upon the filament. The amount of carbon received by any particular section of the filament is greater where the heating and therefore the resistance is high, so that the thin or imperfect portions are brought up to the same strength as the remainder by an increased deposit. At the same time great uniformity of resistance in the filaments is obtained, as while "flashing," a pilot lamp or an ammeter is in series with the filament, so that the thickening can be arrested the instant that the resistance has been reduced to the standard amount. Each filament is flashed singly. The short platinum terminals are temporarily united by a glass bead, and the filament is attached by a carbon cement which is fused on by an electric current, the operation resembling electric welding. When thus secured the filament is placed in the bulb and the terminals fused in.

1702. Incandescent electric lamps. Lent by the Edison & Swan United Electric Light Co., 1890. M. 2359.

Various sizes of this form of lamp are shown, ranging from the miniature lamp for dental or surgical work to the large 1,000-c.p. lamp taking a current of 35 ampères. In the large sizes five or more carbon loops are employed in parallel, their extremities being connected with two metal rings attached to the lamp terminals. For high candle-powers, however, such lamps would only be employed when special requirements have to be met, as the arc lamp is more economical.

1703. Specimens illustrating incandescent lamp manufacture. Presented by Messrs. J. C. Lyell & Co., 1900. M. 3102.

These show the series of operations followed by the Svea Glow Lamp Co.

(1) Bulb as first blown. Originally the glass is in the form of a tube 1 in. external diameter; uniformity in the shape of the bulb is secured by blowing it within a hot iron mould.

(2) The top of the bulb has been pierced, and a short piece of ·25 in.-tube has been prepared for fusing to it.

(3) The ·25-in. tube has been fused to the bulb, for use when exhausting the air.

(4) The stem of the bulb has been shortened and prepared for the attachment of the filament-holder.

- (1*a*) Glass tube from which filament-holder is made.
- (2*a*) Same with end flanged.
- (3*a*) Same with end fused round platinum terminals and copper extension wires.

(5) The filament-holder has had the filament cemented to the platinum terminals and has been inserted into the base of the lamp and there secured by fusing the flange to the bulb stem.

(6) The lamp has been exhausted, by being connected with a mercurial pump, and then closed by fusing the exhausting tube.

(7) The bulb is here shown finished, by the removal by fusion of the stem of the exhausting tube.

(8) Finished lamp. The manufacture has here been completed by the insertion of the bulb into a suitable cap, provided with terminals and means of connection with the usual electric light fitting; four forms of cap are shown, but in each case the bulb is secured into its cap by cement.

Preparation of Filament.

(10) This is the "raw fibre" from which the filaments are made. It is prepared by squirting cellulose in solution through very fine holes and receiving it in a liquid capable of setting the cellulose into an elastic thread.

(11) The raw fibre has been wound upon carbon cylinders, to give the spiral loop, and the whole packed in powdered graphite and baked for

24 hours at a high temperature. After the crucible has cooled the graphite is removed and the filament obtained in the form shown.

(12) Separated baked fibres ready for flashing.

(13) These are the filaments after having undergone the flashing process, by which the conductivity is rendered uniform and brought to the desired standard.

Seven forms of finished lamps are also shown. Iu the elongated type the long filament has a platinum loop supporting it at the top. The frosted lamps are clouded by exposing the finished globe to a sand blast.

1704. Holders for glow lamps. Lent by the Edison & Swan United Electric Light Co., 1890. M. 2358.

Several arrangements are shown by which lamps can be mounted and attached to the fittings on the circuit. Sockets cemented to the lamps and connected with the holders by bayonet joints are usually employed, but simple spring-holders with the leads hooking on to the platinum terminals are also used; the aim in all cases being to secure a ready and efficient connection with the supply circuit. In some of the examples a switch is combined with the lamp socket.

1705. Electric lamp and holder. Lent by the Bernstein Electric Lamp Co., 1891. M. 2380.

These lamps are designed for working in series, so as to miminise the weight of cable and leads required in lighting extended areas. The specimen shown is a standard 16-c.p. lamp requiring a 10-ampère current and 5 to 6 volts, its resistance being about half an ohm; it can also be worked on a 10-ampère arc lamp circuit. The light-giving carbon conductor is enclosed in an exhausted glass globe, and is fitted as a strut between spring terminals, so that should the carbon fail, these terminals will close together, completing the circuit and preventing the extinction of the other lamps which are in series with it.

The holder contains two metal jaws which, when no lamp is inserted, spring together and maintain the circuit, but the lamp when in position separates them and becomes part of the circuit. It is also provided with an auxiliary cut-out which acts, should the cut-out in the lamp not make contact when a carbon fails. The action depends upon the reduction of a button of a mercury compound into metallic mercury when a certain temperature is attained, the highly resisting button being arranged as a shunt to the lamp circuit.

1706. Nernst incandescent electric lamps. Presented by the Nernst Electric Light Co., 1903. M. 3280.

In this lamp, patented in 1897 by Prof. W. Nernst, a slender rod of a mixture of magnesia and various oxides of certain rare metals is employed as the filament or glower, and although protected by a glass globe is not in an exhausted atmosphere. At ordinary temperatures such a rod is a non-conductor of electricity, but, when moderately heated, it becomes a conductor of such resistance that it is rendered and maintained incandescent by the current which then passes.

This initial heating of the glower, to obtain conductivity, was at first accomplished by the aid of a spirit lamp, but it is now more generally attained by the radiation from a surrounding spiral of fine platinum wire embedded in porcelain; when the lamp is switched on, its coil is raised to a red heat by the passage of electricity, but as soon as the glower becomes conductive, the coil circuit is broken by an electro-magnet in series with the glower.

Owing to the resistance of the incandescent rod rapidly diminishing with increase of temperature, it is found advisable to protect against fluctuations in voltage by the insertion, in series with the lamp, of a compensating wire whose resistance rises with increase of temperature.

As the material of the glower is not further oxidisable, a vacuum is not necessary around it, and this permits of a defective lamp being restored by the insertion of a new "replacement piece," consisting simply of a porcelain plate carrying the glower and its heating spiral.

Three examples are shown of complete lamps, and their details :—

(*a*) This is a ·25-ampère lamp, in which the preliminary heating is performed by a spirit flame applied at the hole at the bottom of the globe; its compensating resistance is a fine platinum wire wound round blocks of unglazed porcelain.

(*b*) This is a ·25-ampère self-lighting lamp, having a heating spiral with an electro-magnetic cut-out; as this involves two circuits, the replacement pieces have three terminals, but incorrect attachment is prevented by making the contact hooks of different lengths. Both of these ·25-ampère lamps fit ordinary holders, and are adapted for pressures of either 100 or 200 volts.

(*c*) This is a 1-ampère automatic lamp for 200 volts. Its details are similar to those of the smaller lamps, except that the glower is hollow, and that the series resistance, which is renewable separately, is formed of spirals of fine iron wire enclosed in a glass tube containing an inert gas.

It is claimed for Nernst lamps that the consumption in watts per candle power is considerably less than with carbon filament lamps; the replacement pieces should, however, be renewed after 400 hours' use.

1707. Linolite incandescent electric lamps and fittings. Presented by the Linolite Co., 1905. M. 3407.

In this system of electrical illumination, patented by Mr. A. W. Beuttell in 1901–2, the incandescent electric lamps employed are of a straight tubular form with a carbon filament traversing the length of each. The filament has a convolution in the middle to allow for expansion, and the lamps are mounted end to end in a series of double holders carried in an aluminium reflector of semi-circular cross section, the edges of which are rolled over to form tubes through which the conducting leads pass. The holders are fitted with spring contact pieces and, for low voltage circuits, are so connected with the leads that the lamps are run in parallel, but on circuits of 200 or more volts the lamps are arranged in pairs as in this example, each pair being in series.

The linear source of light thus obtained is useful for shop window lighting, decorative purposes, and lighting a room by reflection from the ceiling, &c.

1708. Tantalum lamp. Received 1906. M. 3456.

In the early days of incandescent electric lighting, filaments of platinum were tried and found to be unsuitable owing to the fusibility of that metal at a temperature slightly above that of incandescence, while other metals having a higher melting-point, such as osmium and tantalum, were not then available owing to the difficulty of obtaining them in the form of very thin wire. In the case of tantalum these difficulties were overcome in 1902–4 by Messrs. Siemens & Halske, with the result that a lamp of the type shown, in which a filament of that metal is employed, was introduced in 1905. The chief advantage claimed for such a lamp in comparison with a carbon filament lamp is the greater efficiency (*i.e.*, less watts per candle power), due to the higher temperature reached. Moreover, as the resistance of a metal increases with a rise of temperature, while that of carbon decreases, a metal filament lamp is not only protected against overrunning, but its luminosity is less sensitive to variations of pressure than that of a carbon lamp.

The tantalum is drawn into wire about ·002 in. diam., of which 25·5 ins. are employed for a 25-c.p. 110-volt lamp. This long length of filament is required owing to the conductivity of the metal, and is arranged in a zig-zag manner between the ends of two sets of radial arms.

1709. Portable electric lamps. Lent by J. Pitkin, Esq., 1886. M. 2875.

Three lamps are shown with accumulator cells, self-contained within their oak cases; the glow lamp has an enamelled reflector and is protected by stout glass. The switch is in vulcanite, on the side of the case, and opposite it are two sockets for the introduction of the charging wires.

1710. Portable electric lamp. Lent by the Edison & Swan United Electric Light Co., 1890. M. 2358.

This is a portable combination of an incandescent lamp and a storage battery, and is intended for use where an explosive atmosphere may be encountered. The battery consists of four accumulator cells in series enclosed in a teak box with a securely fastened cover and handle. The glow lamp, which is of 1 c.p., is attached in front of the case and protected by a thick glass cap. For charging, an E.M.F. of 10 volts and a current of ·5 to ·6 ampère for about 9 hours is required; the lamp gives off its 1 c.p. illumination for from 10 to 15 hours, and the total weight is 7 lbs.

GUN MECHANISMS AND MOUNTINGS.

Munitions of war as such do not come within the scope of this collection, but there are many mechanical problems involved in gun construction that render the subject of considerable engineering interest. A gun is a heat engine, and before the invention of the steam engine Huygens had constructed a form of gunpowder engine, and since his time many inventors have produced such engines for pumping or for giving power in the form of rotary motion; a very compact arrangement for driving piles has been used in which the work was done by gunpowder. It is not possible, however, that a powder-driven engine can have any extensive use, for, independently of the expense in working, a pound of its fuel possesses far less intrinsic energy than the same weight of coal, while in continuous work the thermal efficiency of such an engine is not likely to be greatly superior to that of other heat engines..

The high temperature of the gases liberated by the explosion (about 2,200 deg. C.) and their immense pressure (about 42 tons per square inch when there is no air space) occasioned mechanical difficulties in securing a sufficiently gastight joint that prevented the success of any form of breech-loading musket, although they were being constructed as early as the 14th century. The introduction of a gastight metal-ended cartridge, however, at once solved the problem, and soon rendered muzzle-loading arms antiquated. In big guns, the size of the cartridge was considered an objection to this solution, so that muzzle-loading survived much longer, but the greater size of the breech gave room for a method of packing that was tightened by the gas pressure on somewhat the same principle as Bramah's cup leather. By this means leakage was prevented and muzzle-loading guns were only slowly abandoned; recent practice,

however, has been to use metallic cartridges for all quick-firing guns, *i.e.* up to guns of 6-in. calibre, although there is a tendency now to discard the metallic cartridge in favour of some other form of obturator.

To attain a long range, it is necessary to reduce the resistance of the air to the projectile without diminishing the mass of the shot, and this result is attained by using an elongated form resembling a pointed cylinder. Such a bolt has, however, a natural tendency to travel sideways, as can be seen by dropping a stick from a tower; in an arrow this is overcome by increasing the air resistance of the tail end and many bullets have been partly steadied in this way. By giving the projectile sufficient axial rotation before it leaves the muzzle, the tendency to tumble over during flight can be completely overcome, and this is done by causing the shot to fit helical grooves in the barrel, known as "rifling." This invention is not modern; but, the long or small-bore bullet is chiefly due to Sir J. Whitworth, who by an exhaustive series of experiments determined the correct proportion between the length of the shot and the pitch of the rifling. His grooves were V-shaped, containing an angle of 120 deg., and being six in number his bore became a twisted hexagonal prism. Mr. Lancaster introduced a twisted oval, but Lord Armstrong rifled his guns with many fine grooves and jacketed his shot with lead, which would embed in the rifling when being forced along the bore. The Woolwich muzzle-loaders were rifled with three narrow grooves, into which fitted short bronze studs that projected from the shot; our modern guns are all breech-loaders, and in common with those of other nations are polygrooved, and use shot with a copper band near the base, the arrangement being a development of the original Armstrong system. The first large rifled piece used in the service was a 68-pr. cast-iron gun with the oval bore of Lancaster; this was at the siege of Sebastopol, where its superior accuracy over the smooth-bore guns was remarkably evident and led to the immediate adoption of rifled ordnance by the French.

A great improvement in heavy guns has resulted from increasing the length, partly due to breech-loading, but chiefly through a modification in the explosive by which a less violent but more sustained pressure is secured, so that a greater length of barrel can be profitably used in increasing the velocity of the shot. Steel is used for all parts, while all modern guns have a jacket of steel wire, or tape, wound on under tension in a way that ensures a more equal distribution of the bursting pressure through the material of the gun than does the earlier shrinking method. Increased power and accuracy has rendered it very desirable to reduce the exposure of the gun to an enemy's fire; disappearing carriages resembling the original form of Major Moncrieff (*see* No. 1731) are sometimes used for this purpose.

Small arms have been modified by the adoption of magazine rifles, which contain a store of cartridges that can be fed out one by one, so saving the time lost in loading, but with such weapons it is difficult to be economical with ammunition. The revolver was the earliest successful weapon of this class, but its arrangement is unsuited to long ranges owing to the great leakage of gas. The store of cartridges is sometimes arranged in the stock, or in a tube below the barrel, but more usually in a box beneath the breech. Machine guns somewhat resemble them, but are mounted on carriages and fed from much larger reservoirs; the mechanisms are usually actuated by a hand lever or winch. In Sir Hiram S. Maxim's automatic gun the recoil of the barrel does all the work and at a very high speed, which is, however, under perfect control (*see* No. 1727).

Recent progress has been in the direction of the further development of quick fire, and long guns firing smokeless powder have been introduced, while the use of capped projectiles has greatly increased their average perforating power. The experience gained in warfare during the last decade has suggested the adoption of guns of longer range and heavier calibre, especially for field artillery, and 4·7-in. siege guns mounted on steel carriages are now being manufactured.

1711. Matchlock gun. Woodcroft Bequest, 1903. M. 1655.

The musket was developed during the 14th century from the cannon then in use, by reduction in size and the substitution of a crutch in place of a carriage; the weapon was fired by applying a smouldering cord to loose powder in a touch-hole communicating with the charge. To enable the soldier to simultaneously aim and discharge such a gun or "arquebus," a device resembling the trigger of the crossbow was added, which released a spring finger that then applied the lighted match to the touch-hole.

The matchlock shown is of the primitive construction used by hill tribes in the N.W. Provinces of Hindostan. The forged iron barrel is secured to the stock by strips of leather, and the lighted end of the match is carried by a spring lever connected with the trigger: the short chain at the breech is for holding a pricker, and the socket is for securing the extra length of match carried.

1712. Flintlock musket. Presented by John Bell, Esq., 1879. M. 1660.

In this muzzle-loading weapon a gun flint is clamped in the trigger and strikes against a lever which covers the pan containing powder, which communicates with the charge through the touch-hole. The example shown is the Tower pattern used in the British army at the time of Waterloo. It has a smooth bore, ·75-in. diam., the barrel is 38·5 in. long, and the weight 9·75 lbs.

1713. Breech-loading shot gun. Presented by W. A. Gorman, Esq., 1881. M. 1524.

This a flintlock shot gun with a breech-loading arrangement invented by Mr. Augustus Siebe in 1835. The breech-block forms a continuation of the barrel and is so hinged to the stock that it can stand up vertically. The charge is placed in the breech-block, which is then swung down so as to be parallel with the barrel; the barrel is pulled backwards over an interrupted collar on the block, and then locked by partial rotation of a collar on the

barrel. This rotation is given by a projecting lever that afterwards can be folded parallel with the stock.

The lock is a good example of the final form of the flint and steel arrangement which continued in use long after the introduction of percussion caps in 1818. The piece of flint is held in a screw vice formed on the hammer; the priming powder by which the charge is exploded is contained in a small pan into which the hammer strikes, and this pan is completely closed by a steel cover. When the trigger is pulled, the flint of the hammer strikes along a curved tongue on the cover, at the same time throwing the cover back and exposing the powder in the pan, which is then instantly exploded by the sparks evolved.

1714. Double-barrelled pistol. Woodcroft Bequest, 1903. M. 1656.

This pocket pistol, of the rifled breech-loading pin-fire class, contains some modifications patented by Col. H. G. Delvigne in 1862.

The barrels are in one piece, with a lower lug which fits on a horizontal pin projecting from the breech-block and stock; round this pin the barrel-piece can be turned through 90 deg. for loading, but it can be locked in the firing position by a sliding stop formed with the trigger guard. To secure a convenient grip with so small a weapon, the triggers are actuated by a spring-returned pin, the head of which is under the forward end of the barrels.

1715. Snider rifle. Presented by Prof. John Taylor, M.D., 1876. M. 1661.

The breech mechanism of this rifle, the invention of Jacob Snider, jun., in 1864–5, was adopted in 1866 after a competitive trial, as being the best temporary expedient, pending the introduction of an entirely new pattern of rifle, of altering the existing stock of muzzle-loading Enfield rifles when the introduction of a breech-loader became necessary owing to the superiority in fire shown by such small arms in the Austro-Prussian war of 1866.

About 2 in. of the breech was removed, and its place taken by a block turning over laterally on a pin parallel to the axis of the barrel. A central-fire metallic case cartridge was employed; this was struck by a stout pin passing obliquely through the breech-block and returned by a helical spring. To open the breech, the spring-bolt, which locks the block in position, is withdrawn by a thumb-lever, which also turns over the breech-block. The empty cartridge-case was extracted by an arm which could slide longitudinally with the breech-block by hand so that the cartridge-case could be dropped or picked out.

The hammer, actuated by a flat mainspring, as also the barrel of the Enfield rifle, were retained. The barrel has three grooves; its length is 36·5 in.; the calibre is ·577 in.; the bullet weighed 460 grains, and the charge of powder 70 grains. The rifle is sighted to 950 yds.

1716. Breech-loading rifle. Presented by Alexander Henry, Esq., 1869. M. 1192.

This rifle, patented by Mr. Henry in 1865, has its breech closed by a block that slides in vertical guides; it is moved downwards by the pull of a lever placed outside the trigger guard, and when at its lowest position pulls back a long sliding extractor. The cartridge is fired by a pin that passes through the breech-block, and is struck by the hammer, which has to be independently cocked.

1717. Breech-loading rifle. Contributed by MM. L. Lambin et Cie., 1872. M. 1286.

This rifle has the Comblain breech mechanism which was adopted in the Belgian army. The breech is closed by a wedge block which slides vertically downwards under the action of an enlarged trigger guard that serves as

a lever. The block carries with it a hammer, which is cocked by the act of depressing the block when loading; at the bottom of its travel the block pulls back the extractor.

1718. Breech-loading carbine. Presented by W. Scott, Esq., 1873. M. 1297.

This is a short military breech-loader patented by Messrs. Carter & Edwards in 1869. The breech is closed by a sliding bolt, which, when home, is locked by a partial rotation given by the breech handle. The bolt is in two lengths; the after length, forming the hammer, is retained by the trigger when the breech is closed, so that the action is self-cocking. The front of the bolt has a small extractor hook.

1719. Magazine rifle. Lent by the U.S.A. War Department, 1887. M. 1853.

This is the 1863 pattern of the Spencer repeating rifle which was at one time used in the American army. The breech is closed by a block which rises vertically, and then for the greater part of its motion describes a circular path; it is pulled down and swung backwards by a powerful lever that forms the trigger guard. The cartridges are of the rim-fire type, and are fired by a hammer that is independently cocked, the blow being transmitted past the block by a sliding plate. The store of cartridges is contained in a tube passing up through the butt, and fitted with a long spring by which the foremost cartridge is forced into the breech-block, which, in the act of closing, shuts off the other cartridges, and forces this one home. Extraction is done by a wedge-shaped blade that acts on the rim of the cartridge at one side.

1720. Magazine carbine. Lent by the U.S.A. War Department, 1887. M. 1854.

This is a Spencer repeating carbine with the same mechanism as No. 1719, but one side of the breech and a portion of the stock have been cut away so as to render the action visible.

1721. Magazine rifle. Presented by the Winchester Repeating Arms Co., 1880. M. 1507.

This repeating rifle was patented by Mr. B. B. Hotchkiss in 1869–77. The breech is closed by a bolt action which is locked by a partial rotation of the bolt; a prolongation of the bolt forms the hammer, and on the left side of the breech is a safety stop that locks the hammer, while a similar stop on the right-hand side shuts the magazine, so allowing the rifle to be used as a single-loader. The magazine consists of a metal tube in the butt with a spiral spring to expel the cartridges; it is filled by forcing the cartridges backwards through the open breech.

1722. Magazine rifle. Presented by the Winchester Repeating Arms Co., 1880. M. 1506.

This is a sectioned example of the Winchester repeater, of the 1876 pattern. The breech is closed by a bolt moved to and fro by toggle levers under the control of a breech lever, that also forms the trigger guard. The cartridges are fired by a hammer which is cocked by a continuation of the bolt during the action of opening the breech. When the bolt is back the continued motion of the breech lever elevates a rectangular box that lifts the cartridge from the lower level into line with the barrel, where the breech-bolt forces it home, the cartridge-carrier meanwhile springing down to its former position. In the lower position the carrier is filled from the store in the magazine tube beneath the barrel; the tube contains a long spiral spring

that is continually forcing the cartridges backwards and is filled by introducing the cartridges one at a time through a side door beneath the breech-block. The cleaning rod, cut into five lengths, is contained in a pocket formed in the butt.

1723. Magazine rifle. Presented by the Winchester Repeating Arms Co., 1887. M. 1826.

This is a sectioned example of the 1886 pattern of the Winchester repeater. The breech is closed by a sliding bolt propelled by the breech lever, which forms the trigger guard and also works a vertical wedge that locks the breech when home. The cartridge is taken from the magazine beneath the barrel by an extractor that seizes the base of the cartridge; when the cartridge is fully withdrawn a lever springs up and acts as an inclined guide directing it into the barrel. The magazine is filled from the side of the breech as in the earlier pattern.

1724. Magazine rifle. Presented by the Remington Arms Co., 1881. M. 1511.

This rifle, patented by Messrs. E. Remington & Sons in 1875, has a sliding-bolt breech action, with a hammer at the end of the bolt which is brought to half-cock by the action of closing the breech, and then fully cocked by the thumb. The magazine of cartridges is in a tube beneath the barrel and is filled through a trap below the breech. Pulling the breech-bolt back extracts the spent cartridge and then swings up a guide that has received the cartridge from the magazine; forcing the bolt forwards pushes the cartridge into the barrel and a quarter turn of the bolt then locks it. On the left-hand side is a lever which shuts off the magazine and leaves the incline in position for the weapon being used as a single-loader.

1725. Magazine rifles. Presented by Messrs. Quitmann & Co., 1887. M. 1846.

These are two specimens of a rifle patented by C. F. Mannlicher in 1885 and used by the Austrian army; one is in section to render the mechanism visible. The breech is closed by a bolt which, when home, is locked by a tail piece that is depressed by a guide, no rotary motion being given to the bolt; it is self-cocking, but at the extremity of the breech is a safety lever. The magazine is in a box beneath the breech and contains five cartridges held in a light steel clip by which the whole nest is passed downwards through the breech opening, against a spring that is continually acting to thrust them upwards. The steel clip remains in position, but as the cartridges are used the remainder are forced up by the spring through the clip, the top of the clip firmly retaining the uppermost cartridge until it is forced forward into the barrel by the breech-block; the weapon cannot, however, be used as a single-loader. When the cartridge clip is emptied it drops through the bottom of the magazine and a full clip is inserted.

1726. Pneumatic saloon rifle. Made by the Giffard Gun Co., Ltd. Received 1906. M. 3447.

Proposals to propel a projectile by other means than the gases generated by an explosive compound have often been made. In the weapon shown liquefied gas is used; such a method is, however, only applicable for short ranges, as the volume of the gas, when expanded, is very much less than is obtainable from the same amount of an explosive generating gas at an exceedingly high temperature.

In this rifle, patented in 1889 by Mr. Paul Giffard, a removable cylinder of liquefied carbon dioxide is screwed into the lock below the barrel. At the breech end is a valve having an annular bearing against a screwed stopper through which projects a valve pin. The lock is simple, having a hammer striking against this valve pin; the gas so liberated communicates by a passage with the breech behind the bullet. The amount of gas is regulated

by a screw which limits the stroke of the hammer. The bullet is introduced by means of a plug with a through hole which, when turned through 90 deg., coincides with the bore of the rifle. The barrel is ·303 in. bore and is 26 in. long. The cost of the gas is very much less than that of explosives.

1727. Maxim automatic gun. Presented by the Maxim Gun Co., 1885. Plate XII., No. 1. M. 1627.

This is the original experimental gun made by Sir Hiram S. Maxim for determining the data required for the construction of his automatic gun, in which the energy of the recoil is used to perform the work of discharging and reloading the weapon. As now made, these guns will discharge at any speed up to 600 shots per min., but have a large water jacket round the barrel to keep down the temperature.

In this experimental machine, the barrel with its breech recoils in its guide through about ·375 in., then the breech-block, which is held on to the barrel by clips, is released, and continues its backward motion, assisted by the motion of the barrel, which has a total travel of about 1 in. From the back of the breech block extends a connecting rod to a crank attached to the framing, and provided with weighted arms which act as a flywheel; this crank can swing through about 300 deg., so that when in the forward position with the breech closed it is 30 deg. off its forward dead-centre. When the discharge takes place the recoil drives this crank-shaft round, so opening the breech, which is again closed by the continued motion of the crank. Beneath the breech is a revolving cylinder with projecting leaves, between which cartridges can be placed, and the backward motion of the breech feeds round the cylinder so that the next cartridge is forced by the forward motion of the breech into the barrel. The trigger is attached to the block, and is released by an adjustable stop on the frame.

In the actual guns the trigger may be released by hand or automatically, and the speed of firing is controlled by a dash-pot; the cartridges are fitted in clips on a flexible belt which is carried through the machine by the breech mechanism.

1728. Model of breech-loading cannon. (Scale 1 : 8.) Contributed by Messrs. Maudslay, Sons & Field, 1857. M. 111.

This represents a breech-loading cannon patented by Mr. J. Maudslay in 1854. The breech-block is swung round a vertical axis by a pinion gearing into teeth on the forward face, and into it the charge is inserted. When the breech is closed the block is forced home by a screw at the back, and the charge is fired through a hole in the side of the block. The gun is shown mounted on a pivoted carriage which has a screw elevator.

1729. Model of breech-loading Armstrong gun. (Scale 1 : 4.) Made at the Royal Arsenal, 1867. M. 1650.

Lord Armstrong first submitted his design for rifled ordnance to the War Office in 1854, and was then authorised to construct a 3-pr., which was subsequently re-bored to be a 5-pr. After repeated trials with this and other guns his system was adopted by the Government, and came into general use about 1858.

The construction shown in the model consists of an inner barrel, or "A" tube, of steel, which forms the surface of the bore and receives the rifling; this is encircled with welded iron hoops, shrunk on so as to possess initial tension on Treadwell's system. The coils were made from 2 in. sq. wrought-iron bars, 90 ft. long; these were heated in a long furnace, then withdrawn through an aperture in the furnace door and wound on a roller. When a bar had thus been coiled as closely as possible, the roller was turned on end and withdrawn from the coil, which was then given a welding heat in another furnace and worked under a steam hammer until it became about 2·5 ft. long. When the six lengths required were so prepared, they were

welded together and afterwards turned and bored ready for shrinking upon the A tube. The breech-piece and trunnion ring were shrunk on afterwards.

The projectile was a cylindrical bolt, lead-coated, and slightly larger than the bore; it was introduced through the breech together with the lubricator and powder charge. The breech was then closed by a vent-piece, with a mitred face fitting a corresponding mitre at the end of the bore. This piece was dropped into a recess, and then forced home by a large hollow screw behind it, a large amount of back-lash on the turning handle permitting a hammering action that was of the greatest value in closing or releasing the screw. The gun represented had the following dimensions: Weight, 82 cwt.; length, 10 ft.; diam. of bore, 7 in.; diam. of muzzle, 13 in.; grooves in rifling, 76; depth of rifling, ·06 in.; width of rifling, ·1233 in.; twist of rifling, 1 in 37 calibres; weight of projectile, solid, 110 lbs.; weight of common shell, 90 lbs.; charge R.L.G. powder, 11 lbs.

The gun is shown mounted on a naval carriage and slide, connected to a fixed pivot at the port hole. The slide has a slope forward so that the incline will assist the running out of the gun on its rollers; but before firing, the eccentric axles of the back rollers are turned so that the carriage shall merely slide on the guides. The resistance is still further increased by side clips, or "compressors," that by screws are caused to grip the sides of the slide; a final stop is provided by a stout rope or breeching, rove through the carriage and secured to the ship's side.

1730. Section of a Whitworth gun. Presented by Messrs. Joseph Whitworth & Co., 1867. M. 1651.

This is a portion of the longitudinal section of a 3-pr. gun, with a bore of 1·5 in. and rifling of 3·3 in. pitch, which with a charge of 8 oz. of powder and an elevation of 35 deg. gave a range of 9,688 yds. The small guns of this class, up to 12-prs., were made from a solid block of bronze or steel, but the larger ones were built up in steel in the usual manner.

The distinctive feature of Sir Joseph Whitworth's system of rifling is that the bore is hexagonal with a uniform twist, and that the shot fits the bore mechanically. This bore is obtained by cutting 6 rifling grooves, of an angle of 120 deg., in a circular bore. The quick-pitched rifling that he was thus first enabled to employ permitted of the use of much longer projectiles than had then been used, and gave his guns a degree of accuracy and penetration that had not before been secured.

An elongated shell and a rifled sphere for the gun are also shown.

1731. Model of Moncrieff's disappearing gun-carriage. (Scale 1 : 8.) Lent by Major A. Moncrieff, 1874. M. 1773.

This is a model of a 9-in. muzzle-loading 12-ton gun mounted on Major Moncrieff's disappearing carriage, by which the gun is lowered into a position of safety and is only exposed during the interval of firing; the energy of the recoil performs this work, lifting a counterweight which afterwards re-elevates the gun.

The carriage has a horizontal platform that turns on a central pivot; on its upper surface are secured two notched rails upon which fit recesses in two curved plates that carry the trunnions of the gun and also the heavy counterbalance weight. Inside the carriage are two slotted guides, containing the ends of a pair of links, which are connected by other links to the breech of the gun. By this means the gun remains horizontal as it descends through the rocking of its supports during the recoil. A pawl prevents the return of the gun until released, and a hand gear is provided by which the action of recoil can be substituted during drill. When completely depressed by the recoil the muzzle of the gun is beneath the counterweight, and so accessible for loading; the charge is brought in trucks that run on a platform beneath the carriage.

1732. Model of Moncrieff's hydro-pneumatic mounting for a disappearing gun. (Scale 1 : 12.) Presented by Messrs. Easton, Anderson & Goolden, 1897. M. 2981.

This represents a 10-in. 18-ton muzzle-loading gun, mounted behind a breastwork, as in the earlier arrangement shown in No. 1731; but, instead of the energy of the recoil being absorbed in lifting a weight, it is here employed to compress air, which is afterwards used to lift the gun for the next discharge.

The carriage turns on a central pivot, and is supported upon circular rails upon which it can be trained. On the top of the carriage is a horizontal shaft, carrying a pair of bell-crank levers, the upper and longer arms of which support the trunnions of the gun. The lower and shorter arms are united by means of connecting rods to the crossheads of a horizontal ram, which works in a horizontal cylinder inserted into the lower part of a storage air-vessel. When the gun is up in the firing position, the ram is protruding from the cylinder which, together with the lower part of the air-vessel, is full of water; the upper part of the air-vessel contains air of such a pressure that, when the gun is fired, the recoil and the weight of the gun force in the ram, and by further compressing the air, store sufficient energy to again raise the gun.

Between the cylinder and the air-vessel is a "recoil valve," opening from the cylinder into the vessel, so that the water forced in by the ram cannot return, thus retaining the gun in the loading position. The raising of the gun is effected by opening a valve, which allows the water under the pressure of the compressed air to pass into the cylinder.

1733. Model of hydro-pneumatic recoil carriage. (Scale 1 : 8.) Presented by Messrs. Easton, Anderson & Goolden, 1897. M. 2980.

This represents an experimental gun mounting in which the energy of the recoil is absorbed by fluid resistance. The trunnions of the gun are carried in bearings in a saddle that slides on the carriage, which is pivoted on a fixed pin. On each side of the saddle is a cylinder, in which slides a hydraulic ram attached to the lower carriage. Each ram has through it an axial hole, by which water under pressure can be admitted for running out the gun, or through which the water in the cylinder can pass to a weighted relief valve which maintains such a pressure during the recoil as will absorb the energy represented by the momentum given to the gun, which momentum is equal to that of the shot. As this is not a disappearing mounting, the energy to be absorbed is less than that when the gun sinks also; with the addition of an air-vessel the energy of the recoil can be utilised for running out the gun in a similar way to that adopted in the mounting shown in No. 1732.

1734. Bullet-making machine. Contributed by James Munro, Esq., 1867. M. 1034.

This machine, invented in 1857 by Mr. W. H. Ward, is for the manufacture of bullets, of any form, from squirted lead wire; for each bullet a portion of the wire is cut off and then compressed into a mould, by a punch that forces the lead to completely fill it. The machine is double-ended and makes a bullet at each end for every revolution of the main shaft; this shaft has on it a cam that reciprocates horizontally an enclosing loop that connects the two plungers that compress the lead. The two coils of lead wire are arranged above, and the lead from each is, by a feeding clip, pushed into self-acting nippers which retain the end while it is being sheared off; the nippers then open and the short piece drops in front of the die, into which it is pushed by the plunger, and when the end of the die is reached is compressed so as to completely fill the mould; the finished bullet is then dropped out below. The machine is stated to be capable of turning out 3,000 bullets per hour, without any waste of material.

1735. Specimens illustrating the manufacture of the cartridge for the ·303 rifle. Lent by the Birmingham Small Arms & Metal Co., 1893. M. 2498.

These are excellent examples of the flow of solids when subjected to great pressure, and show the various stages necessary to prevent the change in any one operation from being so severe as to cause rupture.

For the bullet, the lead core is at once pressed into shape and is afterwards forced into a cupro-nickel envelope, this harder jacket being necessary to ensure that the bullet shall take the rifling. The jacket, by the series of stages shown in the whole and sectional specimens, is stamped from a disc into a shallow cup. This is gradually decreased in diameter and thickness and increased in length as indicated. It is then cut off, filled with its leaden core, and the end closed over, so finishing the bullet.

The solid cartridge-case has entirely replaced the built-up type at first employed. Starting with the disc, the series of processes illustrated resembles that followed with the bullet envelope, but is more complicated owing to the formation of the recess for the cap, and the necessity for forming a flange at the base of the cartridge. A complete and sectional specimen of the finished loaded cartridge is also shown.

LOCKS, KEYS, HINGES, BELLS, ETC.

Under this heading have been arranged numerous inventions of general domestic use which could not be included in any of the preceding classes. Most of these fittings are so common and elementary that they hardly require representing, while their history is altogether uncertain; possibly the more important of the contrivances were independently invented at various times in different parts of the world.

In the case of locks and safes, however, there has been a continuous growth as the improvement in the means of attack rendered more complete defence necessary; but the weak points in the various locks have more generally been detected by the locksmith rather than by the thief, the latter evidently considering the destruction of the lock or safe the more promising and expeditious course.

Probably the earliest form of lock had a keyhole of a peculiar shape, requiring a key resembling that of the tap of a beer barrel. The protection, or ward, being visible, was very readily fitted and would probably then be arranged within the lock so as to be less easily copied; such warded locks remain the most general domestic form, but their value is hardly due to any serious difficulty that would be found in picking them or in fitting a fresh key.

In the Egyptian lock of about 2,000 years ago, the bolt was a hollow square bar of hard wood, that had to be drawn back before the door could be opened. Above the bolt were several pins, or tumblers, which dropped into holes in the bolt and so prevented its motion; but a key provided with pegs could be inserted in the bolt and would then lift the tumblers to the right height and permit of the bolt being moved by the key.

For many years locksmiths neglected this important tumbler description of lock, contenting themselves with locks in which a large number of wards were fitted, so rendering an intricate key necessary; but, with the bolt maintained in its position by a spring which the key overcame.

In 1778, Robert Barron introduced a lock with several tumblers, each of which secured the bolt; this construction of lock is still the most generally adopted arrangement for security and is known as the lever lock. Barron fitted his lever locks with wards also, but the additional security that the wards afford is so slight that they have now been almost abandoned. In the lever lock there are several tumblers or levers, each of which holds the bolt in position, but will not prevent it from sliding if lifted to a definite height, neither too high nor too low; the stepped form of the key raises each tumbler to its exact required height and then by the continued motion the key moves the bolt. The number of possible combinations of the various positions that a few levers can take is so enormous that the mathematical chance of picking such a lock would suggest that to do so would be practically impossible; but, the slightly greater freedom of a tumbler when in its released position renders it possible to set each one separately, and in this way such locks have been repeatedly picked.

Joseph Bramah, in 1784–98, introduced a cylindrical lock which is still constantly used. The barrel of the key had notches in it, each of which depressed, to a definite arbitrary amount, a blade which was acting as a tumbler; the construction greatly differed from that of the lever lock, but the principle and the defects of the two are almost identical. Chubb and Hobbs have greatly improved the construction of the lever lock and, by fitting an independent locking pawl suitably covered, have reduced the probability of picking it much nearer to its mathematical limit, so that such locks are now but seldom mastered, except through their destruction by explosives or by protracted mechanical work.

Relying upon the large number of possible combinations of a limited number of letters, the so-called letter locks have been constructed, usually in the form of padlocks. Such locks will open without a key, provided the letters are turned into the definite order, usually so as to form a certain word; as with the simple lever lock, however, the correct arrangement can usually be discovered by a similar treatment, the letters being settled one at a time, irrespective of the remaining ones.

A very ingenious and valuable form of lock where great security is required is the time lock, in which, after the safe door has been closed, it is impossible for any key to unlock it until a certain number of hours have passed, determined by a clock contained within the lock; owing to the inconvenience that would result should the clock stop, a triple or quadruple arrangement is often adopted.

Dial locks, or combination locks, have now been so improved that the "trial and error" method of opening them is useless, and they are usually employed for fire-proof safes in conjunction with the multiple arrangement of time lock. The joints of safe locks have sometimes been penetrated by liquid nitro-glycerine, and this has caused the introduction of automatic bolt mechanism, which requires no holes through the door. Powerful spring mechanism is employed to shoot and retract the bolts when the correct time has elapsed.

Dispatch boxes are usually made without any locks, but have the covers secured by spring catches; when once closed these boxes can only be opened by destroying the cover.

A form of lock that has during recent years been extensively applied is that which is released by placing in it a suitable coin. The idea is very old, as Hero of Alexandria about 150 B.C. describes such appliances fitted to what is now known as an automatic machine. The Egyptian apparatus worked by the weight of the coin, but in nearly all modern machines the coin in its passage merely releases a trigger that otherwise keeps the box or door closed.

1736. Reproductions of Pompeiian locks. Made by Signor Castellani, 1869. M. 1642.

Two specimens are shown, the small one for locking a chest with a hasp fastening, the other a door lock; the latter has been opened to render the construction visible. The metal case is fitted with a wood block that forms a guide for the metal bolt. Above the bolt are four pins, pressed downwards by a spring, and passing through holes in the wood, and corresponding holes in the bolt; these pins, or tumblers, secure the bolt when it is shot, and must each be forced out of its hole in the bolt before the bolt can be withdrawn. Unlocking is performed by a hooked key, having four pegs by which the tumblers are lifted and the bolt moved.

1737. Wooden locks. Contributed by G. Price, Esq., 1868. Plate XII., No. 2. M. 1066.

These are two ancient Scottish locks from a farmhouse on the banks of Loch Shiel, Moidart. Though of rough and primitive construction, they contain the leading features of lever locks; a sliding bolt is prevented from moving by tumblers, unless the latter are lifted by a key of proper shape. In both cases the tumblers slide vertically at right angles to the bolts, and drop into notches in the latter. The key, when inserted, is lifted, and lifts the tumblers.

1738. Wooden lock. Presented by Sir W. C. Trevelyan, Bart., 1870. M. 1643.

This lock was brought from Thorshaven in the Faroe Islands in 1821, and is a more complex form of No. 1737. The key is of hard wood, but the rest of the construction is of deal. The bolt has enlarged ends which limit its travel, and two sets of notches on the upper surface into which projections on four gravity tumblers above can enter. Between the tumblers the wood of the lock is left as a series of wards, necessitating a key of peculiar construction.

1739. Old lock. Presented by J. Hughes, Esq., 1894. M. 2574.

This lock was taken from the door of the parish church of Sacomb, Herts, in July 1855, when some repairs were in progress; it is probably the original lock put on when the church was built about 1450.

The lock has two wards, and on the back of the bolt is a spring that is lifted by the key before the bolt is shot, as in a tumbler lock. The pipe-key has been made by folding over and brazing a piece of sheet iron; the ring is brazed and the wards are welded on.

1740. Ancient iron keys. Contributed by G. Price, Esq., 1868. M. 1066A.

These are 14 specimens of ancient iron keys for locks, with various intricate arrangements of wards.

1741. Locks. Contributed by Messrs. J. T. Needs & Co., 1871. M. 1221–2.

These are padlocks and locks for books, desks, cupboards, &c., of the construction patented by Joseph Bramah in 1784. The key has notches of unequal depths in its end and a lug projecting from its side. The notches depress spring tumblers arranged radially in a barrel until they will allow of the barrel being turned by the lug of the key. An eccentric pin on the barrel moves the bolt.

1742. Padlock. Contributed by the Commissioners for the Exhibition of 1851. M. 372.

This a large padlock, by Messrs. Moreton & Langley, in which security is obtained by a complex arrangement of wards, as indicated by the intricate shape of the key.

1743. Chest lock. Contributed by the Commissioners for the Exhibition of 1851. M. 373.

This lock, by Messrs. Moreton & Langley, is for a box or chest. The hasp has four staples, into which pass T-shaped projections from one sliding bolt. The hasp is locked down by turning the key either way, and is unlocked only when the key is exactly in the mid position.

1744. Double-action tumbler lock. Presented by C. Hamp, Esq., 1860. M. 374.

This is a peculiar drawer lock, patented by Mr. C. Hamp in 1859. There are two sets of tumblers, and the key is double; both portions act on tumblers, while one moves the bolt.

1745. Drawer lock. Presented by Capt. F. Fowke, R.E., 1857. M. 1769.

This is a small drawer lock, patented by Messrs. Tucker & Reeves, in which the tumblers are of circular form. The key itself does not move the bolt, but enters a kind of sheath armed with a lever for moving the bolt; after shooting the bolt by its motion through the first half circle, the key turns the tumblers through a small arc in making the second half of its circle, and thus secures the bolt.

1746. Door locks. Contributed by G. Price, Esq., 1860. M. 371.

These are specimens of a lock, patented by Mr. G. Price in 1859. There are three door locks, one drawer lock, one box lock, and one padlock. The

fronts are partly cut away to show the arrangement which consists of a number of tumblers, turning on a centre and holding the bolt in position, either forward or back.

1747. Lock and latch. Presented by Mons. G. Bergevin, 1885. M. 1618.

This is a lock patented in France in 1884. The bolt is worked by a rack and pinion movement, the key being a tube with feathers on it, constituting a clutch by which the pinion shaft is turned; the key must move the tumblers properly before this can be done.

1748. Slam locks. Contributed by J. Morrison, Esq., 1874. M. 1332.

These are spring latches for railway carriage doors, arranged to fasten by slamming; they were patented by Mr. J. Morrison in 1870. The latch itself turns about an axis at right angles to the door, and can be raised by the usual handle. The hasp, instead of being formed by a notch in a fixed plate, is a small solid cylinder turning on a vertical axis, and having four deep longitudinal grooves in it. A spring pawl prevents rotation in one direction, but allows it in the other. The latch, when the door is slammed, takes into one of the grooves, and turns the cylinder one-fourth of a revolution; the pawl, catching in the next groove, prevents it from returning, and thus the door is fastened.

1749. Seal locks. Contributed by the Seal Lock & Registering Pressure Gauge Co., 1874. M. 1334.

These are specimens of padlocks, patented in 1871, by Mr. F. W. Brooks, of New York, in which the keyhole is covered with a sliding plate, and this again is covered by a small piece of glass with a pattern on it which, when once inserted, cannot be removed without breaking and destroying it. An outer metal cover shuts with a spring over the glass. The key is provided with a pin on the handle to open the inner and outer metal covers. The key of the small padlock is nearly flat, without any barrel. A supply of small squares of glass accompanies the locks. There is also shown a seal lock for a ballot box.

1750. Coin-opened tobacco box. Presented by T. B. Shaw, Esq., 1896. M. 2946.

This is a form of automatic machine probably made about the beginning of this century, and used for supplying tobacco. The box is divided into two compartments, one containing the tobacco while the other holds the coins. On the cover of the coin receptacle is a slot and curved passage, through which the coin is introduced and led to guides which rest it upon a lever that is kept up by the lid of the tobacco compartment. While so supported the coin is in front of a trigger against which it is forced by depressing a projecting knob; the trigger then releases the cover, which, under the action of a spring, at once flies up, the coin at the same time dropping to the bottom of its locked compartment.

The machine only works with the large copper halfpennies that were in use before the introduction of our present bronze coins; when once open the whole of the tobacco was exposed, but these boxes were used at public-houses, and it was understood that only a pipe-fill was to be taken.

1751. Spring door hinges. Contributed by the Perpetual Tension Propelling Belt Co., 1881. M. 1525A.

These hinges, patented in America in 1876, are for either single or double doors. A helical spring, concentric with the pin, is compactly combined with the hinge and renders the door self-closing.

1752. Model of expanding table. (Scale 1 : 4.) Contributed by Messrs. Edwards & Co., 1882. M. 1538.

This table, patented by Herr R. W. Ruscheweigh in 1878, has several supporting slides below it, to run out and lengthen the table to three times its shortest length.

1753. Atmospheric bell. Presented by J. S. Willway, Esq., 1859. M. 314.

This bell, patented by Mr. J. S. Willway in 1858, has a handle connected to a piston in a small cylinder for exhausting air from a pipe reaching to the place where the bell is to be rung; when the handle is pulled the reduction of the pressure in the pipe causes a distant piston to ring a bell with which it is connected.

An air column, being independent of bends, has great advantages over a moving wire, and modern forms of this bell are being extensively employed; the signal is, however, now usually given by increasing the pressure within the connecting tube.

1754. Magneto-electric bell-pulls. Wheatstone Collection, 1884. M. 2175–6.

In these apparatus, magneto currents which ring an alarm are generated by the motion of the handle, the arrangement avoiding the use of a battery for ringing an electric bell.

In the first, brought out by Sir C. Wheatstone in 1859, the pull unwinds a chain which is wrapped on the spindle of an electro-magnet that can turn in the field of a horse-shoe permanent magnet; the return motion is given by a spring.

In the second, designed by Sir C. Wheatstone and Mr. J. M. A. Stroh in 1871, the bell-handle rotates a ratchet-wheel, which detaches and releases the armature several times for each pull of the handle. The current generated in either case could be used to ring an electric bell, which need have no contact-breaker.

TELEGRAPHIC APPARATUS.

From the earliest times and among savage nations, beacon fires and interrupted columns of smoke have been used to give warning of the approach of an enemy, or the news of victory or defeat. Signalling by combinations of flags is another early method and is still the chief one used at sea; while semaphore signalling, in which a post, having on each side arms which can be readily swung up or down to various angles, is a similar but more expeditious method that within certain limits appears to be unequalled, and is being adopted for naval and military purposes. The semaphore system was brought to perfection by Mons. Claude Chappé in 1794, over the country between Paris and Lille, and the following year was adopted by our Admiralty who erected a series of stations between London and Portsmouth which remained in use till 1845. Such a system was liable to continuous interruption by fog and where a conducting wire can be protected is now only used for temporary requirements.

In 1747 Dr. Watson discharged a Leyden jar through two miles of wire supported on insulating posts on Shooter's Hill, and in 1753 the details of "C.M.'s" scheme (*see* No. 1755) were published in the *Scots Magazine*.

In 1816 Sir Francis Ronalds constructed a successful single-wire telegraph worked by frictional electricity; but further developments of this and other early electric telegraphs using frictional or high-tension electricity were totally stopped by the introduction of magnetic instruments.

Volta, in 1800, discovered the current or low-tension electricity resulting from chemical action, and in 1819 Oersted deflected a magnetic needle by such a current; Ampère's observation, in 1820, of the magnetic properties of a helix, and Sturgeon's discovery in 1824 of the electro-magnet, completed the preliminary researches that rendered magnetic receiving instruments possible. The first needle telegraph was made by Baron P. L. Schilling at St. Petersburg between 1825–32 (*see* No. 1757). Prof. K. A. Steinheil, in 1837, produced a working magneto-electric telegraph in which the sounds produced by needles striking bells of different tones were observed; in a subsequent telegraph, symbols were indicated by a code of dots variously arranged in two parallel lines, these being marked on a paper strip by a tube pen fixed to the needle. Steinheil in 1838 erected a line of about six miles of galvanised iron wire between Munich and Bogenhausen; he was the first to employ the earth as the return conductor for low-tension currents.

Sir C. Wheatstone and Sir W. F. Cooke took out their first patent in 1837 for "giving signals and sounding alarums at " distant places by means of electric currents transmitted " through metallic circuits" (*see* No. 1759). The first actual working telegraph was erected between Paddington and West Drayton (13 miles) in 1838–9; the wires were carried in a tube a few inches above the ground. The instruments were soon simplified so far as to require only two wires, and a telegraph was erected between Paddington and Slough (18·5 miles). Many of these double-needle instruments remained in use until recently; they survived longest for train signalling, and in the collection there are numerous examples of them by different inventors. Messrs. Cooke & Wheatstone subsequently introduced a single-needle instrument which is still largely used by the General Post Office, railway companies, &c., in places where the work is light and the operator not highly skilled; the speed averages 25 words per minute. The first line opened to the public was in 1845, between London and Gosport; in 1870 the various lines in the kingdom were purchased by the Post Office at a cost of £10,880,000.

In America as early as 1832 Prof. S. F. B. Morse had turned his attention to the subject of telegraphy, and by 1835 had devised a working model, in which he used cast type (*see* No. 1756) set up in a line in the transmitter; by the regular travel of the type the circuit was closed at the necessary intervals of time. Prof. Morse constructed a line between Washington and Baltimore in 1843–4 with funds granted by Congress. He found it possible to make the signals by hand with a simple

key (*see* No. 1837). The armature on the receiving instrument had a to-and-fro motion which embossed long and short lines on a moving slip of paper; it was subsequently found very fatiguing to the eye to read this slip so that the instrument has been supplanted by an inkwriter. Herr Th. John, an Austrian engineer, in 1854 brought out as a substitute for the style a disc revolving in ink. Many inventors have turned their attention to this instrument (*see* Nos. 1814–20), amongst the most successful being Messrs. Siemens & Halske (*see* No. 1814). The speed of these inkwriters averages 45 words per minute. Another outcome of the Morse embosser was the "sounder," now almost universal in America and used also in this country, where it replaced Bright's bell instrument (*see* No. 1799); the operator on the Morse embosser found it easier to listen to the click of the armature against the upper and lower stops than to read the slip. The sounder is perhaps the simplest of all telegraphic instruments; it can be read faster than the operator can write, *i.e.*, at the rate of 35 to 40 words per minute.

In 1838 Edward Davy patented a chemical telegraph, which is interesting as being a success at the time although left undeveloped, and also as the forerunner of Sir Alexander Bain's receiver (*see* Nos. 1801–2). The latter was at one time the only recording instrument in England, but was superseded by the Morse embosser; it has such great rapidity that it may again come into favour.

A writing telegraph was invented by Mr. J. W. Walker in 1853, in which a tracing point was deflected sideways by being fixed to an armature placed between two electro-magnets; the pen was held in contact with a moving slip of paper. Somewhat similar is Lord Kelvin's siphon recorder for submarine telegraphy. Cowper's writing telegraph records in ordinary characters (*see* No. 1834).

In Messrs. Cooke & Wheatstone's patent of 1840 is described a step-by-step revolving disc telegraph, in which the letters or symbols are successively visible through an opening in the dial, the particular one it is desired to signal being allowed to remain visible for a longer period than the others. This was modified later to an instrument with an open dial on which the symbols were indicated by a pointer; many forms of these are shown in the collection. Siemens's dial telegraph was brought out in 1848 (*see* No. 1795), and was largely used on Russian and German railway lines. These A B C or dial instruments are chiefly employed on private and rural lines, as they require no battery and can be worked by an unskilled person at a speed of 5 to 10 words per minute. Instruments which would record the message in ordinary roman type have been successively introduced by Messrs. Wheatstone (*see* No. 1821), P. A. J. Dujardin (*see* No. 1830), J. W. Brett (*see* No. 1822), and Hughes (*see* No. 1824). This last is the only one which has been extensively employed in Europe.

By means of the duplex system of telegraphy two messages, one in each direction, can be sent simultaneously over one line, while quadruplex telegraphy, suggested by Stark and Bosscha in 1855 and made practicable by T. A. Edison in 1874, permits of two messages in each direction. In the multiplex system, which was proposed by Meyer in 1873, and depends upon the synchronous motion of rotating arms at distant stations, several messages can be sent over one wire without any restriction as to direction.

Batteries.—The current necessary for telegraphic work is usually generated in batteries consisting of individual cells coupled in series. Several forms of Daniell, Leclanché, and bichromate cells are used, but in recent years secondary batteries have been introduced and their employment is extending.

Lines, Cables, and Insulators.—The conductors first used were invariably of copper, on account of its low resistance—about one-sixth of that of iron. For aerial lines, galvanised charcoal iron wire is now generally employed, although copper is again coming into favour owing to the greater strength and conductivity of that now manufactured. The first wires used in this country were insulated in wood and asphaltum (*see* No. 1866), but poles and insulators were adopted in 1839; a historical series of insulators is shown in Nos. 1868–70.

As early as 1848 Werner von Siemens successfully laid a telegraph conductor across the bay of Kiel. In 1850 a single copper wire insulated with gutta-percha was laid between Dover and Cape Gris Nez, but after a few messages had been sent it was worn through by rubbing on the rocks. However, in 1851, Messrs. J. & J. W. Brett laid a cable between the same points and on September 25th transmitted the first messages (*see* No. 1822). The plan adopted was to inclose insulated copper conductors in a sheath of protecting wires (*see* No. 1875); this method was followed in nearly all subsequent cables. The great weight and cost presented serious obstacles to establishing an Atlantic cable, but they were overcome by the Atlantic Telegraph Co. in 1858; on August 5th of that year the first signals were received through 2,050 nautical miles of wire (*see* No. 1876); but the insulation soon broke down. In 1866 a successful Atlantic cable was completed, and now there are no less than 12 living cables across the Atlantic.

Owing to the researches of Maxwell, Hertz, Marconi, and others, it has been made possible in recent years to communicate by means of electro-magnetic waves between stations not connected by wires.

1755. Photograph of the Charles Morrison memorial. Presented by A. P. Paton, Esq., 1890. M. 2342.

This is taken from a plaster cast at the Watt Monument, Greenock, commemorating the electric telegraph constructed or proposed in 1753

by "C.M.," believed by some to be Charles Morrison, an inhabitant of Renfrew. He appears to have employed frictional electricity and a separate insulated wire for each symbol; the receiver noted the attraction, by a ball attached to the wire, of a paper slip about ·125 in. below it, on which was the symbol.

1756. Relics of Ronalds's telegraph. Lent by H.M. Postmaster-General, 1894. M. 2675.

These are the dial and part of the conductor of the telegraph which Sir Francis Ronalds (b. 1788; d. 1873) laid down in the garden of his house in the Upper Mall, Hammersmith, in 1816.

He employed a frictional electric machine to charge the line, and at each end had a pith-ball electroscope that collapsed when the line was discharged. At the two stations were dials revolved synchronously by clockwork; the dials were marked with the alphabet, but were masked by front plates that left only the uppermost letter visible. The sender discharged the line when he saw the desired letter, and the receiver noted the letter at which the pith-balls collapsed. By the use of a code, a word, or even a whole sentence, could be conveyed by two or three discharges. Ronalds made his first experiments through 8 miles of overhead wire suspended by silk from hooks in horizontal bars. He then laid down his underground line: "a trench was dug in the garden 525 ft. in length and "4 ft. deep; in this was laid a trough of wood 2 in. sq., lining the "inside of it with pitch, and in this trough tubes were placed through "which the wires ran." The joints between the glass tubes were made with soft wax, "the trough was then covered with pieces of wood screwed "down upon it while the pitch was hot; these also were well covered with "pitch and the earth then thrown into the trench again." Some of this line was dug up in 1862.

The invention was brought to the notice of the Admiralty, but it was deemed "wholly unnecessary," and Ronalds seems to have allowed his discovery to lapse.

In the same case are shown insulators and type cast in 1832 by Prof. S. B. F. Morse for his electric telegraph.

1757. Copy of Schilling's electric telegraph. Made by the British Telegraph Manufactory, 1877. M. 2194.

This is a copy of a portion of the telegraph, preserved in the Imperial Academy of Sciences, St. Petersburg, which was the outcome of experiments made by Baron P. L. Schilling in 1825–32.

The receiver part of the instrument consists of a galvanometer with a horizontal needle suspended by a silken thread. The needle carries above it a disc of paper painted black on one side and white on the other; by the deflection of the needle to right or left two primary signals were obtained. The instrument was made almost "dead beat" by a plate on the axis dipping into a bath of mercury beneath.

The alarm call shown consists of a horizontal needle suspended in a coil and so arranged that when deflected by the passage of a current it strikes a trigger gear that releases the escapement of a clockwork alarm. The currents were first transmitted by placing the ends of the line wires in a bath of mercury, but afterwards a simple key was added.

1758. Early advertisements of the electric telegraph. Received 1876. M. 1972.

These are two handbills on one sheet, printed in 1845, announcing the exhibition of Messrs. Cooke & Wheatstone's telegraph between Paddington Station and Slough, a distance of 18·5 miles.

1759. Five-needle instrument. Lent by H.M. Postmaster-General, 1876. Plate XII., No. 3. M. 1970.

This instrument was included in 1837 by Messrs. Cooke & Wheatstone in their first patent for improvements in giving signals by electric currents; a single-needle telegraph was, however, already known. The instrument was employed on the London and Birmingham Railway between Euston and Camden Town, and also on the Great Western Railway between Paddington and West Drayton, but did not remain long in use.

Five galvanometers or magnetic needles and coils were used, arranged in a horizontal row on the vertical diamond-shaped dial; stops were placed to limit the deflection of the needles. Each needle was operated by a separate lever fitted with two finger keys, so arranged that a current could be sent in either direction. When signalling two needles were simultaneously deflected in opposite directions, and the point of intersection of their centre lines on the dial indicated the letter to be read off. Twenty letters could thus be signalled, and by employing the needles singly the ten numerals could be transmitted; these numerals were placed on some instruments on the margins of the lower half of the dial. To obtain a closed circuit when the needles were used singly, a sixth lever and line wire were provided.

The letters C, J, Q, U, X, and Z were not represented on the dial, other letters or combinations of letters being used instead.

1760. Four-needle instrument. Lent by H.M. Postmaster-General, 1876. M. 1973.

This was brought out by Messrs. Cooke & Wheatstone in 1838.

It is a modified form of the five-needle instrument, the reduction in the number of needles being obtained by the use of one deflection in signalling certain letters. The keyboard has 10 keys and the line five wires.

1761. Henley's needle instruments. Lent by H.M. Postmaster-General, 1876 and 1888. M. 1987–9.

In 1848 Messrs. W. T. Henley & Thomas Forster patented a needle telegraph, using a magneto-electric current generated by the movement of the pedal keys, and the invention was worked by the Magnetic Telegraph Co. The needles can only be deflected to one side of their vertical position, and their motion is limited by two stops; the needles remain against them and do not return to the vertical position until a reverse current is sent. The code used in the double-needle instrument was identical in principle with the present single-needle code, while that used in the single-needle instrument was a modification of the Morse alphabet, duration of the deflection of the needle being observed. On the axis of the outside needle is a small bar magnet which swings between the poles of a semi-circular electro-magnet; the bar magnet is pulled from one pole to the other by reversing the current.

The transmitting portion of one of these instruments is also shown: it consists of a laminated permanent horse-shoe magnet, between the limbs of which coils are fixed. The cores of the coils are magnetised by the intervention of soft iron armatures fixed to the pedal key, the movement of which reverses the direction of the magnetic flux through the cores.

1762. Needles and coils. Lent by H.M. Postmaster-General, 1876. M. 1993.

This is a series of the needles and coils successively used by the Electric Telegraph Co.

(*a*) Messrs. Cooke & Wheatstone's coil of 1837, with needle and axle. It consists of two coils of cotton-covered wire wound on wood bases; the needle is between the coils.

(*b*) Circular coil wound with cotton-covered wire, with the needle and axle patented by Mr. William Reid in 1847.

(*c*) Circular coil with needle and axle patented by Mr. Edward Highton in 1848.

(*d*) Mr. S. A. Varley's coil. This was introduced in 1856 to prevent the needle from being demagnetised or even reversed in magnetism by lightning. Instead of a small permanent magnet a soft-iron needle resembling a two-pronged fork is used; it is arranged in the field of two permanent bar magnets.

(*e*) Brittan's coil. In this also the needle inside the coil is of soft iron and magnetised by an adjacent permanent magnet.

(*f*) Mr. C. E. Spagnoletti's coil patented in 1869; the soft iron needle is magnetised by two permanent horse-shoe magnets.

(*g*) Theiler's coil with two iron needles in it magnetised by the poles of a permanent horse-shoe magnet.

(*h*) Holmes's coil, containing a needle which is diamond-shaped.

1763. Double-needle instruments. Lent by Messrs. Reid Bros., 1876. M. 1974–5 & 7.

These are two of Messrs. Cooke & Wheatstone's instruments of 1837 which were used on the line between Paddington and Slough in 1842, and in 1845 created much interest through their having prevented the escape of a murderer.

Owing to the frequent failure of one of the line wires of four or five needle instruments, it was soon found by the operators that the alphabet could be formed by two needles only, if advantage were taken of repeated momentary deflections. The coils and needles are similar to those of the five-needle instrument, but the code was different, since the symbols were indicated by deflections of one or both of the needles; two-line wires were used. An alarm which could be cut out by means of a handle at the side of the instrument was placed at the top. A later instrument is also shown differing only in form and in that it is without an alarum. All three instruments are fitted with "drop" handles.

1764. Double-needle instruments. Lent by H.M. Postmaster-General, 1876. Plate XII., No. 5. M. 1976 & 8.

One is a Cooke & Wheatstone instrument of 1837 and is similar in general arrangement to No. 1763, but without an alarm, as it was found that the click of the needles was sufficient to call the attention of the operator. It is fitted with "crutch" handles.

The other is a smaller instrument, dated 1850; four fluted ebony keys are used instead of handles, and a modified form of the single-needle code is engraved on the dial in addition to the code in No. 1763.

1765. Train signalling instruments. Lent by H.M. Postmaster-General, 1876. M. 2184 & 6.

Each of these consists of several single-needle instruments arranged in a common frame, and both examples are from the terminal station or headquarters of the system controlled.

The earlier instrument was used in 1840 on the London and Blackwall Railway, to signal for starting and stopping the endless cable by which that railway was then worked. There are five single-needle dials, each serving a separate station; below each dial is a drop handle by which signals could be transmitted.

The later example is Sir W. F. Cooke's "block" instrument used about 1845 on the Norfolk Railway between Norwich and Ely. It is very similar to the above, but the central dial is also marked with a code alphabet.

1766. I & V instrument. Lent by H.M. Postmaster-General, 1884. M. 2185.

This instrument, included in Sir Alexander Bain's patent of 1843, was so called from the two letters used to describe the code seen on its face; it

was adopted chiefly for train signalling and the example shown was used on the Edinburgh and Glasgow Railway.

Two semi-circular magnets fixed to a brass bar with similar poles facing were used to deflect, according to the direction of the current, two pointers one above the other; the one moving to the left pointed to the letter I, and the other moving to the right pointed to the letter V.

1767. Single-needle instrument. Lent by J. A. Warwick, Esq., 1876. M. 1982.

This early instrument is marked "W. F. Cooke invenit," and was used by the Electric Telegraph Co. in 1846 on railway circuits.

The code used closely resembles that of modern instruments, right and left hand movements of the needle being made by currents through a single line wire. It is fitted with the early crutch-handle commutator for transmitting.

1768. Single-needle instrument. Lent by H.M. Postmaster-General, 1876. M. 1983-4.

These were patented by Messrs. H. & E. Highton in 1848 and used by the British and Irish Magnetic Telegraph Co.

The signals were indicated by right and left hand movements of a drop-needle, fixed to the axis of a permanent horseshoe magnet within a circular coil (*see* No. 1762). The tapper key in the base is similar to No. 1835. The smaller instrument is a later form.

1769. Dering's single-needle instrument. Lent by H.M. Postmaster-General. M. 1986.

This instrument, patented by Mr. G. E. Dering in 1850, was used by the Electric Telegraph Co. Telegraphs on this principle were placed in the Bank of England, and also used to some extent on the Great Northern Railway.

The movement of the needle is effected by means of electro-magnets having their axes in the plane of motion, instead of the coil used by Wheatstone and others.

1770. Double-needle instrument. Lent by H.M. Postmaster-General, 1884. M. 1981.

This instrument, used by the Electric Telegraph Co. in 1846, resembles No. 1763 in its construction. The case was designed in the Gothic style to harmonise with the architecture of the Houses of Parliament, where the instrument was used.

1771. Experimental double-needle dials. Wheatstone Collection, 1884. M. 1999–2001.

These double-needle instruments were probably made for experimental purposes before Messrs. Cooke & Wheatstone took out their patent of 1845, in which they are described.

They are attempts to increase the action of the current on the needle by introducing iron cores into the coils, by using several coils, or several needles.

1772. Double-needle instruments. Wheatstone Collection, 1884. M. 1979–80.

These are two of Messrs. Cooke & Wheatstone's instruments of about 1845. The needles were only capable of being deflected on one side of the vertical—the left-hand needle to the left and the right-hand needle to the right; one line wire was used, and it was only possible to move one needle at a time. Two finger keys were required for transmitting.

1773. Railway needle instruments. Lent by H.M. Postmaster-General, 1876. M. 2189–90.

(*a*) This is a double-needle block-signalling instrument designed by Mr. Edwin Clark in 1854 for use on the London and North Western Railway. The drop handles can be locked in any position by means of a pin.

(*b*) This is one of Cooke's single-needle instruments of 1844 fitted with a drop handle and used for train signalling on the Norfolk Railway, now the Great Eastern.

1774. Double-needle instrument. Presented by the Institution of Civil Engineers, 1868. M. 1088.

This instrument was used about 1854 for train signalling on the "block" system. It is a simple double-needle instrument with crutch handles.

1775. A B C receiver. Wheatstone Collection, 1884. M. 2036.

This instrument is marked "C. Wheatstone invenit," and was probably made before the improved forms patented in 1838.

Its peculiarity consists in the use of a double dial which would almost double the speed of signalling. There are 24 symbols on each dial; one spring serves two trains of wheelwork, and a single armature vibrates between two sets of magnetic coils. The lever end of the armature is segmentally toothed, and actuates an arbor which alternately forces pallets into the teeth of the escapement wheels on the pointer axes.

1776. A B C transmitter. Lent by Messrs. Reid Bros., 1876. M. 2002.

This is one of the first of this type of instrument, having been designed by Sir W. F. Cooke in 1839; similar ones were tried on the Great Western Railway between Paddington and Slough. The instrument was included in Messrs. Cooke & Wheatstone's patent of 1840.

There is a spring-driven clockwork train which actuates the pointer, controlled by an escapement worked by pallets which are a continuation of a hinged armature vibrating between two electro-magnets. The current is generated by rotating the outer rim of the dial by means of a knob (broken off); the rim gears with two pinions each provided with two discs insulated by ivory and pressed on by springs, forming a make-and-break contact, but the machine is incomplete.

1777. A B C receivers. Wheatstone Collection, 1884. M. 2004–5 & 21.

These are portions of the electro-magnetic telegraph, also known as the revolving disc or dial telegraph, patented in 1840 by Messrs. Cooke & Wheatstone; similar instruments were used on the Great Western Railway between Paddington and Slough.

A disc with all the required symbols on it is fixed on a horizontal axis driven by a clockwork train. An escapement wheel on the axis, and pallets fixed to an armature vibrating between the poles of two electro-magnets, permit the discs to progress one tooth or step for each current and so expose to view successively each letter, the particular one it is desired to signal being allowed to remain visible for a longer interval than the rest. One instrument is shown with the case open; the other has in addition a galvanometer needle to show when a current is passing. In the third instrument the dial itself is moved by a reversed lever escapement, but in other respects resembles the preceding.

1778. A B C receivers. Lent by H.M. Postmaster-General, 1876. M. 2003 & 6.

The first instrument is almost identical with No. 1777, while the other has a fixed dial, the letters being indicated by a pointer attached to the arbor.

1779. A B C transmitter. Lent by H.M. Postmaster-General, 1876. M. 2011.

This instrument, made under Messrs. Cooke & Wheatstone's patent of 1840, is intended for transmitting a current for working A B C receivers (Nos. 1777–8).

The instrument has a dial with 24 radial spokes, one to each letter of the alphabet, J, U, and X excepted, and a zero; these are engraved on the outer rim, and the numerals are engraved twice on the inner rim while there is also the ✠ known as the zero stop. On the same axis as the dial is a spur wheel geared, in the ratio of 12 : 1, with a pinion on whose axis are two electro-magnetic coils whose poles are connected with a piece of soft iron. These coils revolve close to the poles of a large compound horse-shoe magnet, so generating magneto-electric currents. The coils are connected with a commutator which sends two currents in each direction for every revolution of the pinion, so that a current is sent every time the dial is turned through a space equal to that dividing the letters. These instruments work heavily owing to the inertia of the coils.

1780. A B C transmitters. Wheatstone Collection. Presented 1884. M. 2012–3 & 2015.

Two of these instruments are in every respect similar to No. 1779 but are enclosed in cases as they would be in practice. The pointer on the case shows where the spoke, opposite to the letter it is desired to signal, must be brought; one instrument has the spur gearing outside the case.

The third instrument only differs in having the spokes replaced by a handle connected with the dial spindle by a ratchet wheel and pawl underneath. The handle is brought under the letter it is desired to signal and the whole dial and gearing turned in the reverse direction till arrested by the stop; the handle is hinged so that it can clear the stop if desired.

1781. A B C transmitters. Wheatstone Collection, 1884. M. 2007–8.

Both these instruments are intended for delivering successive currents from a battery to work the early (1840) step-by-step instruments (Nos. 1777).

The earlier instrument is incomplete, but is similar to the later one, which has a cardboard dial with letters, numbers, and directions glued on a wheel having 24 radial spokes. On the face of the rim are inlaid 12 ivory plates, and on this face presses a spring connected with the line terminal, while another spring connected with the battery terminal presses against the inside rim, so that currents are sent and broken as the dial is rotated. A third spring, when the pointer is at zero, makes a contact that puts the line to earth ready for receiving a message.

1782. A B C instruments. Lent by Messrs. Reid Bros., 1876. M. 2197–8.

The patent for these instruments was taken out by Mr. John Nott in 1846, and the system was tried for some time on the London and North Western Railway between Northampton and Blisworth.

Two semi-circular horse-shoe electro-magnets alternately attract two rocking armatures, which carry pawls that move a ratchet wheel with a pointer in front of the dial. A simple tapper key is used to send in the currents by which the pointer is worked round to the desired symbol,

indicated by a pause being made. To reduce the "stepping," the alphabet is repeated four times, and the numerals ten times round the dial. For calling attention, an electric alarm is provided.

1783. Early dial instruments. Lent by H.M. Postmaster-General, 1876. M. 2187–8.

These were used for train signalling in 1844 and somewhat resemble Nott's patent; (*a*) is a step-by-step train indicator, used on the London and South Western Railway; (*b*) a similar one used on the South Eastern Railway.

1784. A B C telegraph. Presented by Dr. Henry Wilde, F.R.S., 1897. M. 2987.

This pair of instruments was made by Messrs. Siemens & Halske under the patent granted in 1850 to Mr. E. W. Siemens; one of the instruments is shown with the top removed. The message is transmitted by battery currents, each current rocking a lever that carries a pawl engaging with a ratchet wheel on the index spindle. The receiving dial is in the centre of the instrument while the 30 transmitting keys radiate from it. Each key controls a projecting pin, and beneath these pins passes a contact arm connected with the index spindle, so that as the spindle rotates a current is transmitted for every key passed; but, when the depressed key is reached, the spindle is arrested until the key is again lifted.

Each instrument has an electric call-bell of the contact-breaking construction, together with a switch and a galvanometer; the keys are marked with Russian characters.

1785. A B C telegraph. Lent by H.M. Postmaster-General, 1888. M. 2101.

This voltaic current A B C telegraph was introduced by Mons. Lippens, of Brussels, in 1851.

The transmitter and receiver are combined. On the axis of the transmitter handle is a four-lobed cam-plate by which an arm is caused to vibrate between stops. Each complete vibration sends a pair of reversed currents to line and these actuate the polarised armature of an electro-magnet in the receiver at the distant station. This armature has an arm with two teeth which release the escape-wheel of a spring-driven train of wheels, and on the axis of the escape-wheel is fixed the pointer. Each revolution of the handle advances the pointer four letters. A push button is provided to release the escape-wheel, which flies round to zero at the end of a message.

1786. A B C telegraph. Lent by H.M. Postmaster-General, 1888. M. 2102–3.

This voltaic current A B C telegraph was brought out by Mr. W. T. Henley in 1856.

The transmitter has a dial plate with 26 symbols, and the handle has on its axis a commutator of 26 bars, so insulated and connected that each time the handle is turned through the space between two symbols a current is sent to line reversed in direction to the previous one.

The receiver contains an electro-magnet with semi-annular pole pieces, within which vibrates a magnetised needle which actuates the reversed escapement that moves the pointer. The projecting pin, seen at the side of the dial, is for stepping round the pointer to zero. There is also shown a similar receiver for 30 symbols: it is provided with an electric call bell which may be stopped by a switch in front.

1787. A B C receivers. Wheatstone Collection, 1884. M. 2020 & 2022–5.

These instruments are described in Sir C. Wheatstone's patent No. 1241, of A.D. 1858, where it is claimed that they work with "currents of less energy" and "with greater steadiness, certainty, and rapidity" than previous instruments.

(*a*) and (*b*) the dials have 15 symbols corresponding with the instruments Nos. 1790–1 with which they work. The pointer is fixed on a small escape-wheel of 15 teeth which is propelled by two pallets fixed to two levers connected by a hair-spring; the levers are attached to two small magnets fixed to an arbor vibrating between the pole pieces of two small electro-magnets. A button above the dial serves to adjust the pointer by hand, and in the lower part of the case is placed an alarm. The other instrument only differs in having a sloping dial.

(*c*) and (*e*) were made under the same patent as the preceding, and only differ in having a watch-train at the back of the dial to actuate the pointer, the escapement only being controlled by the electro-magnet, so that feeble currents would suffice to work the instrument.

(*d*) resembles the last, but has no separate electro-magnet for the alarm, it being actuated by the escapement of the watch mechanism; a lever releases the flier arm of the alarm, which rings for a time or till it is stopped by the operator turning the square-ended spindle in front of the box.

1788. A B C receiver. Wheatstone Collection, 1884. M. 2026.

This is known from its shape as the barrel pattern, and was patented by Sir C. Wheatstone in 1858; its construction resembles No. 1787(*a*). The wires are connected with the trunnion so that the inclination of the instrument can be adjusted. The axis of the pointer is vibrated by an electro-magnet and has on it a ratchet wheel which engages with two fixed pawls.

1789. A B C transmitter. Wheatstone Collection, 1876. M. 2014.

This instrument is a slight modification of one patented by Sir C. Wheatstone in 1858, and was probably devised to obviate the tendency to over-running resulting from the inertia of the coils. Instead of spokes vertical plugs are used, any one of which can be pressed down against the resistance of a helical spring, so that on rotation the plugs come into contact with a stop. There are 24 letters and symbols on the dial, and underneath is a wheel with 24 projections on its circumference; pressing against these is a roller carried by a lever, the other end of which is attached to the cores of a double coil fixed in front of a permanent horse-shoe magnet. Every time the dial is turned through the space between two letters, the motion of the cores generates a pair of currents which, transmitted by the line, work the receiving instrument.

1790. A B C transmitter. Wheatstone Collection, 1884. M. 2016.

In this instrument, introduced in 1858, the dial is provided with 30 indentations on its edge, one to each of the letters and symbols; the forefinger is placed in the indentation corresponding to the letter it is desired to signal, and the wheel turned round till the finger comes into contact with a stop which arrests its motion; a pin projecting downwards pushes down a spring that catches the pole piece connecting the magnetic coils and prevents its further rotation. A spur wheel on the dial axis is geared to the pinion on the armature in the ratio of 15 : 1.

1791. A B C transmitters. Wheatstone Collection, 1884. M. 2017–9.

These three instruments are described in Sir C. Wheatstone's patent No. 1241, A.D. 1858.

In the first the dial consists of 30 flexible radial tongues, each representing a symbol and carrying at its extremity a finger button and a pin. The symbol it is desired to signal is pressed and the wheel rotates till it comes into contact with a stop. Below are two wheels, each with 15 equal recesses filed on the circumference, placed so as to break joint. Two springs touching these wheels dispatch a current from a battery every time the wheel is revolved the space between two letters. The zero tongue has a small projection which engages with a stop.

In the other two the dials are similar, but the wheel underneath is toothed and gears in the ratio of 15 : 2 with a pinion which rotates the armature of an electro-magnetic machine.

1792. A B C transmitters. Wheatstone Collection, 1884. Plate XII., No. 6. M. 2028–30.

These instruments were patented by Sir C. Wheatstone in 1858.

By means of a gut band and pulleys, electro-magnetic coils are kept continuously rotating in front of a compound horse-shoe magnet, and by a reducing train drive the vertical spindle of the dial. The 30 spring keys are arranged round the circumference of the dial and any one of them can be depressed; this action allow a tangential horizontal lever to spring into a slot in the key spindle and allows a plate spring to lift up the pointer of the spindle so as to throw it into gear with the train of wheelwork. The spindle revolves until a tongue on it touches the end of the tangential lever, releasing it and the plate spring; the lever remains stationary until another key is depressed. A key when down closes the circuit.

In one instrument gearing replaces the band and pulley, while in the third the horse-shoe magnet is missing, and it appears probable that the instrument has been modified for use with a battery.

1793. A B C transmitters. Wheatstone Collection, 1884. M. 2031–2.

These instruments, patented by Sir C. Wheatstone in 1858, closely resemble the form still used.

The first instrument is similar in principle to those of No. 1792. Each of the 30 keys has a bell-crank lever on the lower arm which presses against the outside of an endless pitch-chain held in position on a series of small pulleys. Only one key remains depressed at a time, as when down it tightens the chain and throws the previously depressed key up again. When depressed the bell-crank lever catches a carrier arm which is fixed spring-tight on the vertical pointer axis and revolves with it, but is thrown out of gear immediately the pointer is arrested and the currents instead of going to line are cut out. The handle, which works the driving pulley, is so pivoted that if turned the wrong way it swings round on to the axis, where it cannot drive. The other instrument is similar but has larger magnets (missing) for long distance working.

1794. A B C telegraph. Wheatstone Collection, 1884. M. 2033.

In a portable box are both a receiver and transmitter of a type used for military purposes.

The transmitter resembles No. 1791 in having the armature and not the coils revolving. The receiver is worked by electro-magnets as in No. 1788, with the escape-wheel vibrating and the pallets fixed. There is a drop handle for bringing the pointer to zero.

1795. A B C telegraph. Lent by H.M. Postmaster-General, 1888. M. 2104.

This magneto-electric telegraph was patented by Sir C. W. Siemens in 1859–62.

The transmitter has a dial of 26 spaces; the handle is connected, by helical spur gearing in the ratio of 13 : 1, with a shuttle armature revolving between the poles of six horse-shoe permanent magnets. A current is sent to the receiver every time the handle is moved through the space between two symbols.

The pointer hand of the receiver is on the same axis as a small ratchet wheel which vibrates between the poles of an electro-magnet; two fixed pawls cause its rotation one tooth for every current.

1796. A B C instruments. Presented by Dr. Henry Wilde, F.R.S., 1897. M. 2988.

The transmitter and receiver, together with a separate receiver, of the dial telegraph patented by Dr. Wilde in 1863 are shown. The electricity used is generated by a small magneto-machine, driven continuously by a treadle and supplying a rectified current. The transmitter consists of a vertical shaft rotated by worm gear from a horizontal shaft driven by the treadle shaft; on this horizontal shaft is a commutator by which four reversed currents are transmitted to the line per revolution. Above the vertical shaft is a plate supporting the transmitting dial through which projects the 30 spring-lifted keys. When a key is depressed it stops an arm attached to the vertical shaft after the corresponding numbers of signals have been transmitted, the slipping of the driving cord permitting of the stoppage.

The receiver, which is more clearly seen in the glass-enclosed example, consists of an index spindle on which is an escape-wheel driven by pallets formed on an arm that is swung by a small magnet fixed between two vertical electro-magnets through which the line current passes. The lower part of the receiver contains a clockwork alarm which, unless switched out, rings when currents are being transmitted; the alarm is wound up by a button that projects from the lower portion of the globular case.

1797. Bright's bell instrument and relay. Lent by H.M. Postmaster-General, 1876. M. 1990.

This was the earliest form of acoustic instrument introduced into Great Britain, where it was used by the British and Irish Magnetic Telegraph Co. Although complicated in construction, it is probably the quickest non-recording instrument extant, but has been supplanted by the Morse sounder.

Two plates or bells of different tones are used to produce a code by means of sound. The hammers are fixed to the armatures of two electro-magnets, being pivoted on a magnetised rod enclosed in a coil. The relay which works the coils consists of two electro-magnets placed side by side, their poles being furnished with pole pieces turning inwards. Between these vibrate the ends of two thin permanently magnetised levers pivoted on vertical axes, the poles of the magnets being so placed that a current in one direction attracts a magnet which closes the local circuit of the right-hand bell and the current in the opposite direction attracts the other magnet which closes the local circuit of the left-hand bell.

There is also a shown a direct bell telegraph, constructed under the same patent, in which the bells are directly struck by hammers attached to the magnetised levers of the relay itself; this instrument was only made as a model and never came into actual use.

The pedal or tapper-key like No. 1835 is used to send the signals.

1798. Whistling receiver. Wheatstone Collection, 1884. M. 2171.

This was introduced by Sir C. Wheatstone as a receiver for use in offices, hotels, &c. The action of an electro-magnet opens a valve which allows compressed air to blow a whistle; a code of long and short notes can be used.

1799. Sounder with galvanometer. Lent by H.M. Postmaster-General, 1888. M. 2087.

This American instrument was adopted by the General Post Office in 1874. The signals are given by sound in the Morse code, the duration of the clicks of the armature lever of an electro-magnet, against the upper and lower stops, giving a "dot" or a "dash." It is less fatiguing to the operator to listen to the clicks than to read the paper tape of an inkwriter, and he can write out the message while he is receiving it.

The galvanometer is added to indicate when a current is passing, but it can also be used as a single-needle instrument.

1800. Bell instrument. Contributed by Messrs. Newton & Son, 1857. M. 98.

This is a call bell, included in Mons. P. A. J. Dujardin's patent of 1847, but it appears also to have been a bell telegraph.

A long magnetic needle is supported on a central pivot so that it can swing horizontally. One end of the needle is placed between the pole pieces of an electro-magnet while the other is between a wooden cylinder and a glass bell, which act as stops. By sending alternating currents from the magneto machine No. 1807, sound signals were produced.

1801. Bain's chemical telegraph. Lent by H.M. Postmaster-General, 1876. M. 2072.

This is an incomplete form of the telegraph patented in 1846 by Sir Alexander Bain. A strip of paper, punched by means of instruments like No. 1847, was placed spirally round a metal drum attached to the line wire, while a spring pressing on the drum completed the circuit except when interrupted by the unperforated paper. At the receiving station a similar strip of paper, but moistened with a solution of potassium ferrocyanide and ammonium nitrate, was pressed on by a steel wire which when the circuit was closed entered into chemical combination and deposited Prussian blue. The patent was purchased by the Electric Telegraph Co. for £10,000., but the preliminary punching of the strip was found too tedious and the system was but little used.

1802. Bain's chemical telegraph. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2073–4.

This is the final form of the preceding receiver as used by the Electric Telegraph Co. (1850) to replace the double-needle instrument. It is now only in use for experimental purposes, but is so rapid and sensitive in action that it may again come into favour.

A strip of paper is drawn off a small gutta-percha bobbin placed inside a short brass cylinder, and over a drum whose surface is silvered; the latter is rotated by a clockwork train having a fan brake. The clockwork is started or stopped by a small lever working between two stops and when in the running position makes contact with the earth terminal. A small wooden roller can be pushed into contact with the silvered drum to keep the paper stretched and at the same time bring the style down to the paper. The style (missing) is made of iron or steel and is in connection with the line wire terminal, while the drum against which it is kept pressed is in connection with the earth terminal. The paper tape was soaked in a mixture of one volume of a saturated solution of potassium ferrocyanide, one volume of a saturated solution of ammonium nitrate, and two volumes of water; the latter salt being deliquescent served to keep the paper damp, When a current passes, the iron decomposes the electrolyte, uniting with the acid radical to form Prussian blue; other solutions, such as potassium iodide, can be used, the iodine liberated from which colours a starch solution. The

Steinheil code, dots in two parallel lines, was originally used but was entirely superseded by the Morse.

Beside the instrument is a gutta-percha wetting trough for preparing the paper; also a number of the bobbins on which the paper was wound.

1803. Chemical recorder. Wheatstone Collection, 1884. M. 2055.

This instrument, contained in a case similar to No. 1810, works on the same principle as Sir Alexander Bain's (*see* No. 1802). Instead of styles, however, two small wheels are employed, connected respectively with the two line terminals, and pressed against the paper strip, which is prepared by passing between two felt wheels revolving in a solution such as that used in Bain's recorder.

1804. Specimen slip from copying telegraph. Received 1876. M. 2196.

This was produced by the copying telegraph patented by Mr. Bakewell in 1848.

The receiving and transmitting instruments are similar, and are rotated by means of weights controlled by a fan escapement and an electro-magnetic regulator that causes them to rotate synchronously. The messages are written either on tinfoil with varnish, or with caustic soda on varnished tinfoil, and then wound round a cylinder connected with the line wire. The receiving cylinder is wound with paper moistened with a solution of potassium ferrocyanide and sodium nitrate and put to earth. Parallel with the transmitting cylinder and geared to it is a screw that carries a style pressing on the cylinder and connected with a battery terminal, while a similar screw carries a style connected with the line wire at the receiving cylinder. These styles describe fine helical tracks as the cylinders revolve, and where the circuit is complete the track of the receiving style will be changed into a blue line, while the breaks caused by varnish will remain white. The telegraph is stated to have transmitted facsimiles of writing at a rate exceeding 200 letters per minute.

1805. Morse embosser. Lent by H.M. Postmaster-General, 1876. M. 2075.

This instrument was used about 1853 by the Electric Telegraph Co. It supplanted Bain's chemical recorder (*see* No. 1802), as it obviated the troublesome chemical preparation of the paper, but reading the embossed marks was found so fatiguing that this instrument was in turn displaced by the inkwriter.

A relay or local circuit is used to work the electro-magnet, whose armature is fitted to a horizontal lever, working between stops at one end and carrying a steel style at the other. When the armature is attracted downwards, the style is pressed upwards against a strip of paper drawn from a large reel by two friction rollers set in motion by a train of clockwork. In the upper roller is a narrow groove into which the style presses the paper, and, according to the time the armature is held down, embosses a dot or dash.

1806. Dot-printing receiver. Contributed by Messrs. Newton & Son, 1857. M. 99.

This instrument was included in the patent obtained by Mons. P. A. J. Dujardin in 1847.

It has an endless sheet of paper passing over a cylinder, and stretched by a roller below. The cylinder is rotated by a clock-train with a fan governor, and at the same time is screwed along axially. A horizontal lever has a pen at one end and a permanent magnet at the other; the pen normally rests in an inkwell below the stretching roller, but when a current passes through

a fixed electro-magnet, the magnetic lever is repelled and the pen rises and makes a dot on the paper. Each letter was represented by groups of dots in a long helical line.

1807. Magneto-electric machine. Contributed by Messrs. Newton & Son, 1857. M. 100.

This was patented by Mons. P. A. J. Dujardin in 1847, and used with his dot-printing telegraph (*see* No. 1806).

The poles of a compound horse-shoe magnet are enclosed in coils, magneto-currents being generated by the rotation in front of them of an armature driven by gearing.

1808. Dot printer. Wheatstone Collection, 1884. M. 2048–9.

This instrument is intended for receiving messages from the transmitters Nos. 1849–50; it is a modification of that described in Sir C. Wheatstone's patent No. 1239, A.D. 1858.

Two styles or pens are rocked by the polarised armatures of two electro-magnets; when the current passes in one direction one armature is attracted and its style depressed, and *vice versâ*; the armatures are returned by a spring. The ink is contained in a shallow reservoir, in which are two holes for the styles so small as to prevent the ink flowing through them, but a style when depressed carries with it sufficient ink to mark the strip of paper passing beneath. The whole frame containing the coils, &c., when not in use, can be tilted so that the styles clear the ink.

The larger instrument is similar, but has each style depressed and raised by separate electro-magnets (one missing). The armature is formed of two curved magnetic rods, as patented in 1845. There is a commutator to enable the instrument to be used for receiving from two lines.

1809. Dot printer. Wheatstone Collection, 1884. M. 2050.

The coils are arranged as in Sir C. Wheatstone's patent No. 1239, A.D. 1858, and resemble those of No. 1808.

The instrument is placed on a case containing a clock-train with regulator for drawing the paper strip along. The lever on the case is for stopping and starting the clockwork.

1810. Dot printer. Wheatstone Collection, 1884. M. 2051.

This is an improved form of the preceding, patented by Sir C. Wheatstone in 1867; only one set of electro-magnets is used, thus halving the resistance.

The coils are vertical, and between the pole pieces is a polarised armature as in No. 1808; its axis is broadened out at the top to a T shape, and alternately moves two bell-crank levers which form the styles. The whole can be lifted clear of the ink by means of a lever. The paper, wound on a large wheel contained in a lower drawer, is drawn through by a clockwork train regulated by a fan governor.

1811. Dot printer. Wheatstone Collection, 1884. M. 2052.

This instrument resembles the earlier form No. 1808, but is mounted upon the lid of a box, and has a pointer attached to each style to indicate when a message is being transmitted, as, when the instrument is in use, the styles are hidden by the brass cover.

1812. Dot printer with alarm. Wheatstone Collection, 1884. M. 2053.

The principle of this instrument is identical with that of the preceding, but the arrangement is different and probably intended for long distance working.

Three sets of horizontal coils have their armatures connected, by links, with a style. On the top of the case is placed a clock-train for drawing through the paper strip, the speed being regulated by a spring-loaded centrifugal governor. The reel is vertical, and placed on a spindle, which is also used to wind up the clock-train of the alarm behind it.

1813. Receiver. Presented by David McCallum, Esq., 1862. M. 344.

This receiver, patented by Mr. McCallum in 1859, and known as a "linoscribe," was specially intended for train signalling, and gives a permanent record.

Cotton thread, unwound from a bobbin, and passing between two electro-magnets on to a reel, receives transverse marks of different colours by being pressed, by wires attached to the armatures, against a ridge supplied with ink. The reel receives its motion by pawls actuated by the armatures. Three bobbins are provided so that three separate records can be obtained.

1814. Siemens's inkwriters. Lent by H.M. Postmaster-General, 1876. Plate XII., No. 7. M. 2076–7.

These instruments, made by Messrs. Siemens Bros., embody their patent of 1862; they superseded the Morse embosser, owing to their sensitiveness to weak currents, and to the greater legibility of the marks made, and are now almost universal wherever recording instruments are employed.

The first form shown is supplied with a signalling key and galvanometer, and is used on lines of moderate length where a relay is not required. The armature of the electro-magnet is attached to a hinged lever working between stops; when no current is passing, it is brought to the upper position by a spring. A plain disc, revolving in a reservoir of ink, is fixed to a continuation of the hinged lever. The paper tape, from a horizontal reel contained in a drawer in the base of the instrument, is carried between friction rollers worked by a clock-train controlled by a governor, the train also revolving the inking disc. Each time the armature is attracted, the inking disc is thrown into contact with the paper strip, and, according to the duration of the current, registers a dot or dash. All the parts can be regulated by screw adjustments. The paper employed is generally coloured and ·5 in. wide; the ink is ordinary printers' ink diluted with olive oil, from which the stearin has been removed by freezing.

The other is a similar instrument, known as Siemens's "local inker"; it is intended to be worked with a relay, and so is not provided with the signalling key and galvanometer.

1815. Inkwriters. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2078–9.

These were patented by Messrs. Digney Frères, of Paris, in 1860; they are known as bottle inkers, from the ink being supplied from a flask-shaped bottle closed by a pad.

In the first, the armature is polarised by a straight electro-magnet, and is actuated by a similar electro-magnet worked by a relay.

In the second, the paper is marked by the armature lever of the electro-magnet forcing it against a disc, whose periphery is kept inked by revolving in contact with a saturated felt roller (missing). Both instruments are incomplete.

1816. Inkwriter. Lent by H.M. Postmaster-General, 1876. M. 2080.

This was introduced by Mr. M. Theiler, but in general arrangement it resembles Siemens's instrument (*see* No. 1814). The marking disc is inked by a metal wheel, placed parallel to it, and rotating in a trough of ink; a felt friction roller transfers and distributes the ink.

1817. Inkwriter. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2081–2.

These instruments were introduced by Mons. L. F. C. Bréguet, of Paris.

In the first, the paper tape is drawn, by rollers actuated by a spring-driven train, along a trough so that a long length is in view and can be read by the operator. The marking disc is forced up to the paper by the electro-magnet, revolves by friction with the paper, and is inked by a felt pad.

In the second instrument, used by the Isle of Man Telegraph Co., the paper tape moves vertically and the marking disc horizontally.

1818. Polarised recorders. Lent by H.M. Postmaster-General, 1876. M. 2083–4.

This class of instrument is for registering in the Steinheil code by identical marks in two parallel lines, representing the right and left beats of a needle. The system compares favourably in speed with the Morse dot and dash, as the dash is three times the length of a dot.

In the first, introduced by Messrs. Siemens Bros. in 1870, there are two electro-magnets, each with a polarised armature carrying a marking disc revolving in an ink reservoir. The discs and the rollers for the paper tape are continuously rotated by a spring-driven train.

The second only differs in that one disc registers in broad and the other in narrow marks.

1819. Recorder. Lent by H.M. Postmaster-General, 1888. M. 2086.

This instrument, patented by Messrs. R. Herring & R. A. Novare in 1870, prints in the Morse code but with the dots and dashes as long and short lines across the tape (Herring's system), so saving tape and also time, as the dashes are made as rapidly as the dots. Although not polarised, it requires a polarised relay and so is practically a polarised instrument.

There are two styles, one with a point that gives the dots, and one with two points that gives the dashes. Each style is worked by a separate electro-magnet; which of the magnets shall act is determined by a polarised relay that moves differently according to the direction of the current received. An inked disc revolves transversely beneath the tape; the single-ended style when depressed forces the paper on to the top of the edge of the disc which thus prints a central dot, the dash is made by the double-ended style which presses the tape on to the disc over a considerable arc. The ink disc and the paper-feeding rollers are rotated by a spring-driven train controlled by a fan regulator.

1820. Polarised recorder. Lent by H.M. Postmaster-General, 1876. M. 2085.

This was introduced by Messrs. Siemens Bros. in 1870, and resembles Mr. Herring's recorder in general arrangement.

The electro-magnets are horizontal and the armatures, to which are attached the marking wheels, are magnetised by permanent steel magnets; when the current passes through the electro-magnet in one direction, only one armature is attracted. A centrifugally governed spring-driven train continuously rotates the paper rollers and the marking disc in their ink reservoir; one of the discs is broad and the other narrow, and they mark lengthwise of the tape in a modified Morse code.

1821. Type-printing telegraph. Lent by H.M. Postmaster-General, 1876. M. 2088.

This is the earliest form and was patented by Sir C. Wheatstone in 1841; it did not come into general use.

The transmitter is similar to that patented in 1840 (*see* No. 1779), and has a wheel with 24 spokes, each corresponding to a symbol; the required one is brought opposite to the stop by a step-by-step movement and a current is sent to line at every step.

In the receiver, steel type are fixed at the extremities of radiating springs on the circumference of a horizontal wheel, which is fixed on the arbor of the dead-beat escape-wheel of a weight-driven train. The escapement is actuated by the armature lever of an electro-magnet restored by a spring. Printing is performed by a separate circuit, exciting a horse-shoe electro-magnet which causes a hammer to strike the type then over the paper; carbon paper was inserted to give the impression.

1822. Type-printing telegraph. Contributed by J. W. Brett, Esq., 1862. M. 831 & 833.

This telegraph was patented by Mr. Jacob Brett in 1845, as a communication from Mr. R. E. House, of New York. The instruments shown are those by which the first messages through the submarine cable from Dover to Cape Gris Nez (*see* No. 1875) were transmitted, in 1851.

The transmitter has 40 buttons or keys, but there are only 29 different symbols, as the commoner ones are repeated. The keys are in two straight lines and when depressed engage with pins disposed in a single helix on the surface of a cylinder, rotated by bevel friction wheels, controlled by a continuously running fly. Fixed to the end of the cylinder is a commutator pressed upon by springs in the line circuit by which intermittent currents are sent to line; when the wheel is released, the cylinder starts revolving at its full speed.

In the receiver is a type-wheel, with the same number of symbols in the same order as in the transmitter, rotated by spring-driven wheelwork. A flier arm on the axis of the type-wheel engages with a tooth on the armature lever of an electro-magnet attracted by the intermittent currents. The type-wheel is further controlled by a ratchet wheel, the pawl of which can only move slowly through being attached to a dash-pot. The paper tape is advanced by a separate train of wheels which also give motion, whenever the type-wheel stops, to eccentrics which move the platen up to the type. Inking is done by a pad wheel.

A call alarm is struck at every revolution of the eccentrics, but is secured by a hook when the instrument is in use.

1823. Type-printing telegraphs. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2096–8.

These synchronous instruments were patented by Mr. M. Theiler in 1854.

In the first transmitter there is a piano keyboard of 29 keys, each marked with a letter or symbol and which when depressed engage with pins or tappets arranged in a single helix on a long cylinder on a shaft above them, which is rotated by a weight-driven train. The cylinder is connected with the shaft by a blade spring, but is insulated from it except when stopped by the projecting tongue of a key. The striking of a key sends a current which starts the printing wheel of the receiver, and the stoppage of the cylinder by the key sends a second current which arrests the printing wheel, and presses the paper upon it. A similar transmitter is also shown in which, however, the keyboard is segmental.

The receiver has a type-wheel rotated by a weight-driven train. Part of the rim of the type-wheel is cut away and this is brought to zero after printing each letter. The printing is done on a paper tape and the type-wheel is inked by a pad-roller containing ink.

1824. Hughes's type-printing instrument. Lent by H.M. Postmaster-General, 1876. Plate XII., No. 4. M. 2091.

This is an instrument brought out by Prof. D. E. Hughes about 1855, for recording in roman type the message transmitted. It is much used on

the Continent, especially in France, but until recently did not meet with such favour in this country, on account of its cost. The instrument differs from the other type-printers in being almost entirely mechanical; both sender and transmitter are identical in construction and are kept running by clockwork, synchronism being secured by the correcting action of the printing signals.

On a piano keyboard are 26 keys, each with two symbols on it, which correspond with raised type on the periphery of the type-wheel; there are also two blank-space and change-case keys. When a key is depressed, one of the pins on the circumference of a circular plate is raised and catches a "chariot" geared with the type-wheel so closing the circuit. The type-wheel is so arranged that when the chariot is stopped by the pin the symbol corresponding to the key is opposite to the printing hammer. The current causes the paper at both stations to be lifted up into contact with the type, and at the same time an electro-magnet releases the detent in the gearing which drives the hammer. The gearing also causes the paper to move forward a space to be ready for the next symbol. The electrical arrangement is very simple; the current which is sent so weakens the polarity of an induced magnet as to cause it to release an armature pulled by a spring; the armature is replaced by a cam. The instrument is sensible to very weak currents, owing to the close balance that can be secured by adjusting the spring.

1825. Type-printing translator for messages. Wheatstone Collection, 1884. M. 2070.

The symbols of the Steinheil code are engraved on a horizontal circular dial, the pointer of which forms a key which, when depressed, forces the corresponding roman characters down upon a tape that is automatically fed through the base of the machine. The type are arranged on a horizontal wheel and are inked by a felt roller.

1826. Type-printing translator for messages. Wheatstone Collection, 1884. M. 2071.

This apparatus is described in Sir C. Wheatstone's patent No. 1239, A.D. 1858. "Its object is to translate the telegraphic signs into the ordinary alphabetic characters."

Externally the instrument has nine finger-stops or buttons. in two rows of four each and one placed above. Within is a clockwork train that tends to rotate a wheel on the circumference of which are 30 type, equally spaced and with their lengths parallel with the axis. When the keys of the upper row are depressed the wheel is allowed to turn 1, 2, 4, or 8 steps, and similarly for the lower row 2, 4, 8, or 16 steps corresponding with the dots of the Steinheil code. Having by the appropriate keys allowed the type-wheel to come into the proper position for printing the letter corresponding to the code symbol, the particular type is pressed down upon a paper tape below by the ninth stop, which, in addition, during its return causes the advance of the paper and restores the type-wheel to its initial position.

1827. Cryptographs. Wheatstone Collection, 1884. M. 2181–3.

These small apparatus were designed by Sir C. Wheatstone especially for telegraphy to ensure secrecy in transmitting a message, but they can also be used for general cipher correspondence.

In the first example an alphabet is arranged in a circle over which turn two pointers set at a constant angle. A message is by this arrangement converted into a series of letters each a constant amount in advance of the intended letter, but such a cipher has little claim to secrecy.

In the other two instruments, by a simple piece of gearing, the angle between the pointers is continually altering, so that only after 27 letters have been transposed does the first transposition again recur. The alphabet

pointer is fixed to a wheel of 27 teeth, the cipher pointer to one of 26 teeth, and both wheels are geared into by a single pinion; a letter of the alphabet is thus represented by all the letters of the cipher; as there are 26 letters and one space on the outer circle and only 26 cipher letters on the inner circle, the space between words is represented by a changing cipher letter so that the cipher is continuous.

1828. Cryptographic embosser. Wheatstone Collection, 1884. M. 2069.

This apparatus, designed by Sir C. Wheatstone, is intended for embossing on a strip of paper the cipher, or the translation of a message transmitted in a cipher, formed on No. 1827.

The dial has a handle and pointer with a spur wheel of 26 teeth, gearing with another of 27 teeth fixed on the axis of a frame round which the type are set. On striking the knob in the centre of the dial, the letter corresponding to the cipher indicated on the dial is embossed on a strip of paper, fed through by a ratchet and pawl, and received in a locked receptacle.

As an operator obtains no assistance from the context when receiving a cipher message, these ingenious devices have not been of practical use.

1829. Type-printing telegraphs. Lent by H.M. Postmaster-General, 1876. M. 2099–2100.

These are step-by-step instruments, patented by Mr. M. Theiler in 1861.

The transmitter resembles Wheatstone's later A B C instruments, and has 28 keys arranged round a circular horizontal dial. The end of each key lever enters a circular ring provided with inclined notches; when a key is depressed it is kept down by the ring, but when a second key is touched the ring is slightly moved, so releasing the other key and locking the second one. Depressing a key also releases a wheel on a spring-driven train, which allows the pointer to travel round till stopped by the key lever; the axis of the pointer carries a commutator which sends to the line wire a reversed current for every letter that the pointer passes.

In the receiver a type-wheel, on the axis of an escapement actuated by a spring-driven drum wound up by the printing mechanism, is controlled by these reversed currents. Printing is performed by a spring-driven train liberated by an electro-magnet on a local battery circuit, closed by a vibratory arrangement which acts when the type-wheel stops.

1830. Type-printing telegraph. Lent by H.M. Postmaster-General, 1876. M. 2092.

This is a modification of the telegraph patented in 1863–4 by Mons. P. A. J. Dujardin; the instrument was used by the Electric Telegraph Co. during 1865 on the line between London and Edinburgh.

The receiver and transmitter are identical. There is a piano keyboard of 28 keys, each of which by a lever raises a pin in the periphery of a circular plate and catches an arm kept revolving by the treadle-wheel below. On the same shaft is a 14-wave face cam which causes a lever to vibrate between stops and sends reversals of the current which release the escapement of the type-wheel step by step. A polarised relay (*see* No. 1844) and local battery are used to work the electro-magnets which act on the anchor of the escapement of the spring-driven wheelwork and prolong the stoppage at the extremity of any particular oscillation; this closes the local circuit of an electro-magnet which does the printing. An electro-magnetic device causes the printing currents to be equal in duration whether a key is held down for a long or a short interval of time. Inking is done by a pad.

1831. Type-printing telegraph. Wheatstone Collection, 1884. M. 2037.

This instrument was made at the British Telegraph Manufactory under Sir C. Wheatstone and J. M. A. Stroh's patent of 1872; it is intended to be worked by an A B C transmitter (*see* No. 1793) or modern form of the same.

The strip of paper or "tape" is unwound from a wheel contained in a drawer in the base of the instrument, and is fed out and beneath the printing wheel by friction rollers moved by a spring driven train. The type-wheel has a single case of 30 symbols on its circumference, and is inked by a roller which is itself supplied from an inkwell by a revolving dipper.

At the top of the instrument is a horse-shoe electro-magnet with a polarised armature which moves horizontally a pair of pallets, which by a step motion rotate an escape-wheel, the amount of rotation being determined by the number of currents received. By an arrangement of epicyclic gearing the movement of the escape-wheel permits a corresponding rotation of the type-wheel, under the action of another spring-driven train. So long as the type-wheel is being rapidly stepped round, a momentum wheel prevents the printing mechanism from acting, but when the interval after a step exceeds a definite period the printing mechanism acts and forces the tape on to the character that is then above the printing point; in this way the currents from a single wire regulate the motion of the wheel as well as that of the tape.

1832. Type-printing receiver. Presented by T. A. Edison, Esq., 1880. M. 1485.

This instrument, patented in this country in 1872 by Mr. Edison, is for printing in roman characters on paper tape; it was originally intended for transmitting stock exchange prices, a large number of these receivers being actuated simultaneously by currents from one central transmitter. The receiver shown is the original apparatus, but is incomplete.

The instrument is mounted on a hollow cast-iron base which contains two horse-shoe electro-magnets, one of which vibrates a lever that presses the type upon the type-wheel, and at the same time feeds it through the machine; the other magnet vibrates a lever which carries a pawl that rotates the type-wheel by a step-by-step motion. The roll of tape was to be supported by arms above the instrument; the inking of the type was performed by an inking roller. By the use of polarised armatures, a single wire with reversed currents worked the two electro-magnets as required.

1833. Drawings of automatic printing telegraph. Lent by Herr C. H. G. Olsen, 1876. M. 2093–5.

Three frames of photographs and drawings of the instrument and its details are shown. It has two principal parts; the punching apparatus by which the messages are prepared, and the printing apparatus used to send the messages.

The punching apparatus has a keyboard of 26 keys, each marked with two symbols and in addition there are change-case and space keys as in the Hughes instrument. The paper strip is carried over a roller which advances some portion of its circumference when a key is touched, until it is stopped by a pin corresponding to the key. Another pin will then punch a hole in the paper strip and also print near it the letter corresponding to the key; this enables the clerk to check the message before transmission.

The transmitting and receiving apparatus have a type-wheel with symbols engraved on its periphery in the same order as on the keys, and a roller of the same diameter as the type-wheel round which the paper strip is laid. Both wheel and roller are rotated at a uniform speed by a weight actuating a train of wheels, and a steel finger with several slits presses the ribbon

against the roller. When a hole in the paper passes, the finger makes metallic contact with the roller and a current is sent to the line wire, causing a magnet to lift the receiving paper strip into contact with the type-wheel. The type-wheels have a speed of 150 revs. per min., and the apparatus transmits 75 messages per hour.

1834. Writing telegraph. Lent by Messrs. E. A. & C. E. Cowper, 1887 & 1893. M. 1875 & 2534.

The experimental transmitter and receiver are shown, together with specimens of the writing and a diagram of the general arrangement. The instruments were invented by Mr. E. A. Cowper in 1878 and have worked successfully through a resistance of 1,000 ohms.

Two line wires are used, one of which transmits a current proportional to the vertical and the other to the horizontal displacement of the transmitter's pen from its central position. This is accomplished by having attached to this pen two jointed rods which transmit the two components of the motion to contact pieces that slide over resistance frames arranged at right angles. These frames are built up of insulated plates set on edge and connected by a wire of high resistance.

At the receiving end each wire circuit actuates its own needle, but the two needles are at right angles and provided with light springs by which they are connected with a single vertical capillary siphon or pen with its point in contact with a paper tape. The paper at both stations is drawn along continuously by clockwork contained in the bases of the instruments.

1835. Highton's pedal key. Lent by H.M. Postmaster-General, 1876. M. 1985.

This key, patented in 1848, was used by the British and Irish Magnetic Telegraph Co., and is similar to those in the base of Highton's instruments (No. 1768); it was also used for Bright's bell instrument (No. 1797), and keys of similar construction are used in modern needle instruments.

The two ebony keys are each fixed to two plate springs connected oppositely with the two poles of the battery. Beneath the keys is a spring contact piece that normally places the line to earth, but on a key being depressed this line contact is broken and one battery terminal put to earth, then the other battery terminal is placed to line; the keys being oppositely connected send oppositely deflecting currents.

1836. Magneto transmitter key. Wheatstone Collection, 1884. M. 2172.

This is intended for working needle instruments. A permanent horse-shoe magnet has pole pieces surrounded by coils; by depressing the key an armature is forcibly detached from the pole pieces and momentary currents are generated in the coil circuit.

1837. Morse key. Lent by H.M. Postmaster-General, 1876. M. 2122.

This simple key, the invention of Prof. S. F. B. Morse, has now, with the code that he also devised, become almost universal. The key shown was used by the Electric Telegraph Co. in 1855 for both the Bain and Morse telegraphs.

It consists of a single pedal, with a finger plate on the end and the hinge between two stops. By a spring it rests normally on the back stop, but when depressed touches the front one. The pedal is in contact with the line, the back stop with the earth and the front one is the battery terminal, so that a depression will transmit a dot or a dash according to its duration, while when up the key leaves the line circuit complete for receiving.

1838. Double plunger key. Lent by H.M. Postmaster-General, 1888. M. 2132.

This was made by Mr. R. B. Jones, and used with a voltaic battery and single-needle instrument for train signalling.

On a mahogany base are placed two vertical keys kept up by springs; when one is depressed the instrument is put into circuit and the needle deflected one way and *vice versâ*.

1839. Double-current keys. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2123–30.

The double-current system of working is used in submarine or long overhead circuits, to remedy the loss of speed due to electrostatic induction. A second and reversed current is sent immediately after the first, to hasten the discharge of the wire, and this necessitates a second battery, with its pole opposite to that of the ordinary line battery, connected to earth, also a special construction of key of which nine modifications are shown:—

(*a*) This was used by the Electric Telegraph Co. in 1855 and known as a slate key from its being mounted on a slate base. The key is normally raised, and, pressing against the back stop, permits the line current to pass when the switch is moved over to the sending position. The key, if depressed, sends a reverse current from the other battery, which actuates a relay and recorder.

(*b*) In this there is no switch.

(*c*) This was brought out by Mr. C. F. Varley in 1854 and is known as a "wheel" key from the shape of the commutator.

(*d*) Is a slightly modified form of (*c*).

(*e*) This key, brought out by Mr. R. B. Jones, resembles Varley's key (*c*).

(*f*) This was brought out by Mr. J. M. A. Stroh in 1868. To switch the connections from "receive" to "send" the key lever itself is turned from left to right through a small angle.

(*g*) Brought out by Mr. Theiler, switches the connection automatically, by a spring which throws the knob and key over through a slight angle so soon as released from the operator's hand.

(*h*) Was introduced about 1868 and was in use by the General Post Office in 1876. The key is similar to Varley's (*c*) and the switch resembles Theiler's (*g*) but is actuated by a handle.

(*i*) This key was devised by Siemens about 1860 for submarine cable working. The upper level is normally raised and puts the connections in the "receiving" order. Depressing the upper into the lower lever makes the connections ready for "sending" and thus obviates the use of a switch; both levers are then held together and worked as one.

1840. "Zinc sender." Lent by H.M. Postmaster-General, 1876. M. 2120.

This is an apparatus used by the Electric Telegraph Co. in 1858 to obviate the effects of electrostatic induction where a double-current key could not be used.

The coils of the apparatus, wound with fine wire to give a high resistance, are placed as a "leak" or derived circuit on the sending end of the line wire. A Morse key (*see* No. 1837) is used, and when depressed a portion of the current passes through the coils, which form part of a relay that, when excited, makes contact with a stop connected with one pole of a small battery for supplying the reversing current; the other pole is connected to earth. A spring is fixed to the tongue of the relay on the battery side to

lengthen the contact. The back stop of the Morse key is in connection with the tongue, so that when the key is raised the reversing current will momentarily pass out to line, until a portion by passing through the coils of the zinc sender moves its tongue to the opposite stop. Thus after each reversal following a marking current, the instrument is ready for receiving, and the receiver can stop the transmitter even while transmitting.

1841. Thomson's double-curb transmitter. Lent by Lord Kelvin, 1876. M. 2199.

This is an apparatus for transmitting double-current signals into a cable. It was made for use on the first Atlantic cable (1858) but was not completed before that cable failed; in conjunction with Lord Kelvin's mirror galvanometer it, however, greatly assisted the early progress of ocean telegraphy. On account of the electrostatic capacity of a submerged cable, ordinary signals lose their distinctness in transmission, but by sending immediately after the charge a smaller charge of opposite kind the duration of the signal is diminished while the received wave is rendered more pronounced. The electrostatic induction, however, still reduces the clearness of the signals to such an extent that mechanical precision in the transmission is of the greatest assistance in reading the minutely fluctuating currents received.

In the instrument shown there is a horizontal shaft rotated by a weight-driven pendulum clock. On the shaft are stepped contact pieces or cams, so arranged with regard to fixed tongues that any charge sent into the cable is immediately followed by a lesser but opposite charge; in this way the double-current working is obtained. To secure uniform transmission, the operating keys, of which there are two tiers of 20 each, when depressed do not directly make the contact but remain down till the revolving shaft attachments complete the circuit, after which each rises successively. Probably the upper 20 keys gave right-hand deflections and the lower 20 left-hand, while so many keys allowed the operator to work in advance of the mechanism when signals were favouring him.

With a simple Morse key scarcely one word per minute could be transmitted through an Atlantic cable, while with this apparatus 15 words are sent in the same time. The automatic transmitters, for which the message has been previously prepared by suitably perforating a paper tape, give a still better result and in a simpler manner (*see* No. 1849).

1842. Polarised relay. Lent by H.M. Postmaster-General, 1876. M. 2108.

With long lines, the currents transmitted become too weak to produce the required signals, and there are great objections to increasing the transmitting battery power. The difficulty is, however, overcome by causing the feeble current received to switch into action a local battery, the current from which then works the instrument just as the line current would have done, had it been of sufficient strength. This device is known as a relay and it is frequently used for sending on a message that has been enfeebled by a long transmission.

The relay consists of an electro-magnet wound with many turns of fine wire so as to work with very feeble currents, while the armature of the magnet moves between stops which are also contact pieces for a fresh battery circuit. If a simple dot-and-dash code is to be transmitted the armature may be of soft iron and returned by a spring, but if reversed currents are to be similarly transmitted the armature is magnetic and such a relay is described as polarised.

The form shown was patented by Mr. E. O. W. Whitehouse in 1854, and was intended to be worked by magneto-currents in the line wire. The armature is a small permanent horse-shoe magnet, carried vertically on pivots, and vibrating between the poles of an electro-magnet. The neutral position is determined by a similar magnet in an adjustable support.

1843. "Varley's mill." Lent by H.M. Postmaster-General, 1876. M. 2118.

This device, invented by Mr. C. F. Varley in 1855, was used by the Electric Telegraph Co. in connection with relays and translators, to increase the duration of contact.

The armature of the electro-magnet works between stops and is rapidly attracted in the usual way, but, when the current ceases, the return is impeded by a lever, which, by means of a cord, is connected with a pulley and fan.

1844. Polarised relays. Lent by H.M. Postmaster-General, 1876, 1884, & 1888. M. 2105, 2109–14, 2116–7, & 2121.

(*a*) This was patented in 1855 by Messrs. C. T. & E. B. Bright, and used by the British and Irish Magnetic Telegraph Co. It is identical in construction with the relay on the receiver No. 1797, but has duplicate electro-magnets and magnetised needles.

(*b*) This was patented by Sir W. H. Preece in 1855, and used for duplex working. There are two magnetised needles on a single axis, vibrating inside duplicate sets of coils; both sets are movable for adjustment, but one set has a micrometer setting.

(*c*) This relay was brought out by Mr. C. F. Varley in 1856. The armature is a bar of soft iron which can swing horizontally on a central pivot, and is enclosed in a fixed coil at each end. The ends of the armature are between the poles of permanent horse-shoe magnets.

(*d*) This was patented by Mr. C. F. Varley in 1856, and used by the Electric Telegraph Co. The electro-magnet has four coils, and the pole pieces are between the two pairs. The armature is of soft iron and suspended by fine wire from an adjustable head; it is polarised by a compound permanent horse-shoe magnet.

(*e*) The relay shown is the earliest form with its armature magnetised by the induction of a permanent magnet; it was patented by Mr. C. F. Varley in 1858 and used by the Electric Telegraph Co. The coil is wound on a core of soft iron and encased at both ends with a cap of the same material; in the central space left between the caps is an armature, shaped to the arc of a circle and carried between centres. The armature is steadied by two adjustable helical springs and polarised by a compound bar magnet placed behind.

An ordinary magnetised needle is arranged beneath the coil and when currents are passing is deflected, so serving as an indicator.

(*f*) This was used in connection with automatic translators about 1862. It works on the same principle as Bright's relay (*see* No. 1797), but with the tongue polarised by the induction of permanent magnets.

(*g*) These were patented in 1865 by Mons. P. A. J. Dujardin for use with his type-printing receiver (*see* No. 1830). The tongue of the relay vibrates between the pole pieces of two straight electro-magnets and is polarised by two permanent horse-shoe magnets underneath. Two small bobbins in front, wound with fine wire, provide a high-resistance shunt, to obviate sparking when breaking contact, as a powerful local battery is required for the type-printer.

(*h*) These two relays were brought out by Mr. R. B. Jones. In the first the armature is formed by two bar magnets secured to a vertical shaft carried between centres and provided with a contact tongue. The poles of the electro-magnet are between those of the two bar magnets.

The second instrument is similar, but has four bar magnets on its armature and the electro-magnet is double.

1845. Polarised relay. Lent by W. Andrews, Esq., 1876. M. 2106.

This is known as the guillotine relay, and was brought out by Mr. Andrews about 1864.

The armature is a semi-circular permanent magnet, placed horizontally and vibrating between two electro-magnets. The upper one is of the ordinary type provided with vertical adjustment, but the yoke of the lower one is replaced by a permanent horse-shoe magnet. The current passes through both sets of coils, which are so wound that one attracts and the other repels the armature.

1846. Non-polarised relays. Lent by H.M. Postmaster-General, 1876. M. 2107, 2115, & 2119.

(*i*) This was made by Messrs. S. W. Silver & Co. about 1864, and used by the United Kingdom Telegraph Co.

The line current passes round an electro-magnet, the armature of which is fixed to a lever that vibrates between stops that make the contacts. The armature is raised by a light adjustable spring.

(*j*) This was brought out by Mr. W. Andrews about 1864, and used by the United Kingdom Telegraph Co. It is known as the "pump" relay, on account of the employment of a small oil cataract cylinder to lengthen the time of contact by delaying the return of the armature.

(*k*) This was designed by Mr. W. Andrews in 1868 for use with Hughes's type-printing instrument (*see* No. 1824), and was used by the United Kingdom Telegraph Co.

The relay is adapted for working with the short currents employed in that instrument; the relay currents are of uniform strength and independent of the line current.

1847. Punchers for chemical telegraph. Lent by H.M. Postmaster-General, 1888. M. 2066–7.

(*a*) This was designed by Sir Alexander Bain for preparing the tape used in the transmitter of his chemical telegraph, patented in 1846 (*see* No. 1801).

Two handles are fixed to levers with which circular punches are connected; the levers, by a ratchet and pawl, feed the tape from a reel through the instrument. The lever on the right of the handles actuates the feed motion without punching, so giving the spaces between letters and words; the combinations of circular perforations give a code similar to Steinheil's.

(*b*) This was made by Messrs. Theiler & Sons about 1858, for use with Bain's chemical telegraph.

It punches in a code of long and short holes resembling that of Morse. The arrangement closely resembles that of Wheatstone; there are three keys, the right-hand punching oblong and the left-hand square holes through the tape, while the centre key feeds the paper along without punching it.

1848. Punchers for automatic telegraph. Wheatstone Collection, 1884. M. 2056–8.

These instruments are designed for perforating the strip of paper, or tape, used in automatic transmitters. The first puncher patented by Sir C. Wheatstone (1858) perforated the tape in two parallel lines representing the signals, while a central line of holes indicated the spaces between letters and words. The code used was a modification of Steinheil's (1836), in which the number of holes in succession on either side of the central line was limited to four.

In these three instruments, patented by Sir C. Wheatstone in 1867, the tape is punched with a uniform line of central apertures, the signals as before being indicated by side perforations.

There are three keys fixed to bell-crank levers, lifted by springs and each controlling a punch. The tape, from a reel, is drawn down a vertical groove by means of a small disc and lever worked from the central key lever. The

outside key levers punch the side holes representing the symbols and by a projection on the centre key depress it also. The latter is depressed independently for the spaces between letters and words. The three instruments only differ in the form of hole punched.

1849. Automatic transmitters. Wheatstone Collection, 1884. M. 2038–44.

There are instruments for sending into a line wire by mechanical means the irregular sequence of currents representing a message. Several operators may be employed preparing the messages for the transmitter, which then forwards them at a speed which is restricted only by the mechanical limits of the receiving instrument. The instruments, which are fully described in Sir C. Wheatstone's patent No. 1239, A.D. 1858, are intended to transmit currents from a battery.

(*a*, *b*) In these a handle, through spur-gearing, drives a flywheel and a crank which reciprocates a small frame, through which passes a tape having a message on it as a series of holes punched by a perforating instrument (No. 1848). On this frame is a spring clip, which holds the paper during one swing of the frame, but is raised during the return movement.

There are three wires on the reciprocating frame, held up by light helical springs, so that a slight end pressure is capable of keeping them depressed. "The middle wire only acts a guide to the paper during the cessation of the currents," while the two outside wires are provided with contact-makers, by which a current is sent to line in one direction when one wire is elevated, and in the opposite direction by the other.

(*c*) This closely resembles *a* and *b*, but is intended for transmitting unreversed currents only.

(*d*, *e*, *& f*) These three instruments differ from the preceding, in having the contact wires or needles driven by linkwork from an eccentric.

1850. Automatic magneto-transmitters. Wheatstone Collection, 1884. M. 2045–7.

In the first instrument, patented by Sir C. Wheatstone in 1858, the voltaic battery is replaced by a magneto-electric machine; owing to the fluctuations of the current generated by the latter, it is connected by gearing with the transmitter.

There are two coils revolving in front of a compound magnet of 13 horse-shoes; single helical spur-gearing is employed, and if the handle is turned the wrong way the pinion slides out of gear. The transmitter is fixed between the horse-shoe magnets, and driven by gearing at twice the speed of the main spindle.

The other two instruments are described in Sir C. Wheatstone's patent of 1860, and are improvements on the preceding, intended for working longer lines. Currents of greater uniformity and strength are generated by using two sets of compound horse-shoe magnets and quadruple coils, the armatures of which only revolve. The transmitting arrangement is similar to No. 1849.

1851. Punchers for automatic telegraph. Wheatstone Collection, 1884. M. 2059–62.

These modifications of the preceding punchers are described in Sir C. Wheatstone's patent of 1867.

They each have three keys with rubber buffers, which are struck by small stamps, held one in each hand, so that the work of punching is done by the arms instead of by the fingers. There are five punches so arranged that the right-hand key punches four holes, the left-hand key three holes, while the central key punches a single hole. The paper is fed through by a roller and a roughened lever, which is moved when any of the three key levers is depressed. Slight variations are seen in the arrangement of the punchers and the feed mechanism.

1852. Pneumatic puncher. Lent by H.M. Postmaster-General, 1888. M. 2063.

In this puncher, designed by Sir C. Wheatstone, compressed air is employed to do the work entailed in forcing the punches through the tape.

Each of three piano keys moves a separate piston valve, which admits compressed air from a reservoir to a cylinder, the piston of which is packed with a cup leather and lifted by a spring. The piston rods are vertically above the keys of a puncher like No. 1848.

1853. Electrical puncher. Lent by H.M. Postmaster-General, 1888. M. 2064–5.

This puncher, designed by Sir C. Wheatstone, utilises electrical energy to drive the punches through the paper. Three light keys, when pressed, complete the circuits of three horse-shoe electro-magnets, the armatures of which actuate the keys of a simple puncher.

1854. Automatic puncher for A B C telegraph. Wheatstone Collection, 1884. M. 2068.

This instrument, patented by Sir C. Wheatstone in 1870, is intended to punch through a strip of paper a number of holes, corresponding with the number of steps the pointer passes from zero to each particular letter. The dial is similar to that of an A B C transmitter; the pointer is driven by the ontside handle and bevel gearing.

1855. Time-signal transmitter. Lent by H.M. Postmaster-General, 1876. M. 2167.

This is an incomplete example of an arrangement used in London in 1852, for transmitting a time-signal over ten lines simultaneously. The circuits are each provided with a spring contact key, and these are arranged radially from a common centre; above them is a weighted ring which, when released by an electric trip gear, drops and closes all of the circuits. The mechanism was covered by a bell-glass, but could be set by an external knob that by means of a lever in the base communicated with the interior.

1856. Switch for time-signalling. Lent by H.M. Postmaster-General, 1888. M. 2168.

This instrument, made by Messrs. Reid Bros. in 1861, is a relay for firing time-guns. It consists of a vertical galvanometer, the needle of which when deflected completes the circuit of the firing fuse. The stop of the needle is insulated from the rest of the instrument, and forms one end of the firing circuit, while the needle and the rest of the body form the other terminal; for this reason the whole instrument is enclosed in an insulating protecting case, which is provided externally with terminal screws and a switch.

1857. Multiple switches. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2162–3.

One of these is the earliest switch used for double-needle instruments. and was fixed at Normanton in 1857. It consists of a vertical spindle with a pointer, turned by a milled head. Projections or knobs on the spindle press against springs connected with the line wires. Four different sets of wires can be switched on by four quarter turns of the milled head; the knobs in the centre always give "earth."

The other switch is similar, but has only two sets of connections.

1858. Universal switches. Lent by H.M. Postmaster-General, 1885 & 1888. M. 2164–5.

These are devices by which, where numerous lines are brought to a centre as at a telephonic exchange, any two can be put into communication.

The larger switch was fixed at York in 1860. It consists of a vertical board, having secured to it 12 parallel horizontal bars and 12 vertical ones. The bars are all insulated from each other and form the terminals of the two systems. By metal plugs any vertical bar can be placed in contact with any horizontal bar.

The smaller board is a Swiss pattern, and has eight bars in either direction. The contacts are made by plugs that are screwed through the top bars into holes in the lower and transverse ones.

1859. Two-line and bell-switch. Lent by H.M. Postmaster-General, 1888. M. 2166.

This is a simple switch used for private A B C instruments. The terminals are arranged on the top of a circular board, on which is a winch handle that moves a finger enclosed in a recess below the board. A spring contact piece connects the centre with one terminal, and other springs are lifted by the finger of the switch, so making contact with them, and at the same time breaking their contact with pieces upon which they otherwise press.

1860. Call alarms. Wheatstone Collection, 1884. M. 2009–10 & 2034.

These were made under Messrs. Cooke & Wheatstone's patent of 1840, and were designed for use with the earliest A B C instruments; they are clockwork alarms released by a current from the distant station.

(*a*) In this alarm the armature of an electro-magnet carries a rod that catches against pins on a flywheel, but clears them while a current passes; the fly is on a spring-driven clockwork train that drives the hammer by an escapement.

(*b*) In this example the stop projects into a hole in the wheel which, when the stop is withdrawn by a current, keeps running till attention is obtained.

(*c*) This is a later form, and was chiefly used for train signalling. By the call current a clockwork escapement is released, and by additional gearing it is arranged that many blows are struck on the bell by a centrifugal hammer during a single beat of the escapement.

1861. Call alarms. Wheatstone Collection, 1884. M. 2027 & 2035.

(*d*) This is a clockwork alarm for use with A B C instruments, and is similar to the alarm in the base of the barrel receiver No. 1788. Between two electro-magnets is swung a light magnet with two pallets on its extremity engaging with three teeth on a long arm that stops the clockwork. The passage of two or three currents is therefore necessary before the arm releases the train, so that an accidental shake cannot start the bell ringing. The arm is replaced by a lever at each revolution of the second motion arbor of the train, and there is a switch by which the alarm is cut out.

(*e*) This was made by the British Telegraph Manufactory about 1865. It closely resembles the preceding, but two currents must be sent before the arm releases the double centrifugal hammer.

1862. Call alarm. Lent by H.M. Postmaster-General, 1876. M. 2133.

This was made about 1860. An arm, attached to the armature of the electro-magnet, pulls over a weighted lever which falls against another lever

that acts as a stop to the centrifugal hammer of a spring-driven clockwork train. The duration of the ringing is determined by a cam like a Geneva-stop which engages with a pin on the second lever. There is a switch in front for cutting out the bell.

1863. Thunder pumps. Lent by Messrs. Reid Bros., and H.M. Postmaster-General, 1876. M. 2192–3.

These appliances, patented by Mr. W. T. Henley in 1853, were used by the Electric Telegraph Co. for generating alternating currents which rang call-bells.

They are magneto-electric generators with reciprocating armatures, the currents being generated as the armatures, with the coils, are vibrated in the field of a compound horse-shoe magnet, by a hand lever.

1864. Railway signal bells. Lent by H.M. Postmaster-General, 1818. M. 2160–61A.

The smaller instrument is for train signalling, and was introduced by Mr. W. T. Henley. A hammer driven by a clock-train is arranged between two bells which it strikes alternately when in action. The speed of the striking mechanism is regulated by a flier, and a small lever prevents rotation of the flier, except when the lever is withdrawn, by the action of the signalling current on an electro-magnet.

The larger instrument was used at the entrance to a tunnel and has a single but more powerful bell. The controlling electro-magnet, which was carried on a sliding platform under the bell, is now missing, but the action of the whole arrangement is similar to that described above.

1865. Ragon's bell. Lent by H.M. Postmaster-General, 1888. M. 2161.

This is an electric bell, introduced by Mons. Ragon, in which a hammer fixed to the armature of an electro-magnet strikes a gong, while the armature of another electro-magnet allows a plate, with the word "called" on it, to drop in front of an opening in the case. A plunger button restores the indicator to the upper position; there is a simple Morse key in front for transmitting signals.

1866. Portion of underground insulated wires (1837). Presented by the Electric and International Telegraph Co. Another lent by H.M. Postmaster-General, 1876. M. 1032 & 1971.

These are portions of the telegraph line laid down between Euston and Camden Town by Messrs. Cooke & Wheatstone in 1837; the specimens were dug up about 30 years later,

The arrangement consists of a wooden rod of trapezoidal section, in the top and two sides of which five copper wires were inserted in grooves containing a resinous material and blocked up with strips of wood, the whole being afterwards coated with a protecting compound.

1867. Wire joints for aerial lines. Lent by H.M. Postmaster-General, 1884. M. 2156A.

(*a*) This was the first kind employed, and resembles a bellhanger's joint made by simply looping the two wires and lapping them over for a distance of 1·5 in. on each side.

(*b*) The next improvement was to clamp the loops together by a bolt and nut, but like the earlier method the contact obtained became defective owing to oxidation.

(c) This joint known as the "Britannia" was brought out by Mr. Edwin Clark, and is that now invariably used. The ends of the wires are slightly turned up, laid side by side and lashed together for a length of about 3 in. by a serving of finer wire; the whole is then soldered over, so forming a metallic contact that is not affected by any racking stresses.

1868. Insulators. Lent by H.M. Postmaster-General, 1884. M. 2232.

Several insulators of patterns used between 1837 and 1847 are shown, on a pole of the type used by Sir W. F. Cooke.

(a) Iron wire, and (b) three-strand copper wire, both passing through Cooke's original goose-quill insulators, used on the line between Paddington and West Drayton, 1838–9.

(c) Cooke and Wheatstone's original ring insulator, 1840.

(d) Double cone insulator original form, 1845.

(e) Double shed insulator (1847) in which the hook that carries the line wire is insulated by mastic cement in a cavity at the top of the insulator.

(f) Split form of double cone insulator, used for replacing broken ones.

1869. Insulators for railway bridges. Lent by H.M. Postmaster-General, 1888. M. 2233.

Five ring-insulators of Messrs. Cooke & Wheatstone's 1840 pattern are shown, secured to a short staff.

1870. Insulator. Contributed by F. N. Gisborne, Esq., 1860. M. 740.

This insulator, patented by Messrs. F. N. Gisborne & F. O. J. Smith in 1859, consists of a globular cup surmounted by a short spike and having two crooked projections on the top, the whole globe being hollow to admit the end of the bracket for attaching it to the post. The line is made fast, when stretched, by catching under the crooks and pressing against the spike. Both bracket and insulator are of enamelled iron.

1871. Insulators. Contributed by Messrs. S. W. Silver & Co., 1860. M. 741.

Six insulators of various patterns are shown, all made in vulcanite, which, although an expensive material, is economical where stone-throwing is prevalent, as in addition to its toughness its appearance has a protective action.

1872. Insulators. Presented by the Russian Imperial Telegraph Office, 1877. M. 2235.

These are white porcelain double-shed insulators of a pattern used in Russia. Large and small sizes are shown, also the iron bracket used for attaching them to the poles. On the top of each insulator are two lugs between which the wire can be placed when erecting.

1873. Documents relating to submarine telegraphy. Contributed by J. W. Brett, Esq., 1862. M. 2227.

In one frame is shown correspondence between Messrs. J. W. & J. Brett and H.M. Government (1845–9); also the concession for 10 years from 1849, granted by the French Government for a submarine line between Dover and Calais; also certificate of provisional registration (1845) of the first ocean cable company.

In two other frames are four water-colour drawings of incidents which occurred in the laying of the first deep-sea telegraph cable, uniting Spezzia, Corsica, and Sardinia. The cable, manufactured by Messrs. Glass, Elliott & Co., was 110 miles long, weighed 8 tons per mile, and was laid in June 1854.

1874. Portions of submarine cables. Contributed by J. W. Brett, Esq., 1862. M. 830.

In this case are sections and particulars of cables laid in the years 1851–62 between Dover and Calais (*see* No. 1875), Dover and Ostend, Spezzia and Corsica (*see* No. 1873), and other short European routes.

1875. Portions of submarine telegraph cable. Lent by T. R. Crampton, Esq., 1885. M. 2459.

This formed part of the first submarine cable, laid in September 1851, between the South Foreland, Dover, and Cape Gris Nez, near Calais, a distance of 21 miles. Twenty-four miles of the cable were supplied, but this was found half a mile too short, and more had to be manufactured. On October 18th, 1851, communication was established, and messages transmitted with Brett's instrument (*see* No. 1822); the cable remained in use till 1875.

It consists of four copper wires, ·064 in. diam., insulated with two coverings of gutta-percha; these, with a core of yarn, were then covered with tarred hemp, the whole being protected with a sheathing of 10 galvanised wires ·28 in. diam., each wound helically on it. The diam. is 1·31 in., the circumference 4 in., and the weight 5·8 tons per mile. The insulation of this specimen, tested in 1885, was found to have remained unaltered.

1876. Atlantic cable relics, 1857. Contributed by J. W. Brett, Esq., 1862. M. 835, 2228–9.

On the wall is a chart, prepared by the first Atlantic Telegraph Co., of the proposed route of the cable, showing also the connections on the Continent and in America, together with a section of the bed of the ocean and the depths of soundings along the route from Valentia, Ireland, to Trinity Bay, Newfoundland, a distance of 1,640 nautical miles.

A portion of the original cable is shown; it consists of a conductor of seven copper wires ·028 in. diam. twisted together and insulated with gutta-percha, then covered with tarred hemp and protected externally by 18 strands of twisted iron wires of the same number and diameter as the copper conductor. The outside diam. is ·625 in., the circumference 2·06 in., and the weight 1 ton per mile. Communication was established in August 1858, but after transmitting 366 messages the insulation broke down, and within a month from its completion the cable was useless.

An induction coil used in connection with the cable is also shown.

1877. Portions of submarine cables. Presented by the Telegraph Construction and Maintenance Co., 1867. M. 1027–31.

These are portions of the second (1865) and third (1866) Atlantic cables. The second broke when about two-thirds of it had been laid, but was raised, spliced, and completed in the following year by the S.S. "Great Eastern" after laying the third cable. The two cables are similar except at the shore-ends, and several of the same type were subsequently laid.

(*a*) Two deep-sea portions (1865), one of which was recovered from a depth of 11,700 ft. The total length of the cable was 2,184 miles and the weight 1·52 tons per mile.

(*b*) Shore-end (1865). This part of the cable was protected by a sheathing of 12 strands of three twisted galvanised iron wires ·22 in. diam., making the outside diam. 2·3 in.

(*c*) Deep-sea portion (1866). The conductor consisted of seven copper wires ·05 in diam., insulated with gutta-percha and spun with hemp, protected by 10 iron wires ·095 in. diam., each served with five yarns of tarred manilla put on helically. The outside diam. is 1·12 in.; the total length 2,133 miles, and the weight 1·52 tons per mile.

(*d*) Shore-end (1866). This part of the cable was protected by a sheathing of 12 iron wires, ·45 in. diam., covered with a layer of tarred hemp, the whole being 2·6 in. diam.

1878. Vacuum lightning arresters. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2134–6.

Arresters are designed to carry away the great rush of current that results from a lightning flash near a line, and so prevent injury to the operators or the instruments. The charge in a line, from lightning, is of such potential that it will leap air gaps or other resistances that are quite impassable to the battery current, and it is upon this fact that the action of most arresters relies.

(*a*) This protector was invented by Mr. C. F. Varley in 1847, although not patented till 1861, and is for the protection of an underground line connected with an overhead one. From the line, wire is led to platinum terminals fixed into a glass globe, in which is also a wire connected with the earth. The line terminals end in points close to the earth wire, and by exhausting the air from the globe the resistance of the gaps is so reduced as to leave a ready path for high-tension electricity.

(*b*) This form of arrester was brought out by Mr. Varley about 1856, and is designed for protecting six line wires. It consists of six metal points, each one connected with a line wire, and fixed radially in close proximity to a ring connected to earth; the whole is covered with a glass bell-jar (missing). Two short tubes are added, one of which probably contained a chemical that absorbed the gas in the bell, and the other mercury, which acted as a barometer column.

(*c*) This is a smaller and modern form of the vacuum arrester (*a*), and is is intended for a single line.

1879. Serrated-plate lightning arresters. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2140–1.

These arresters, made by Messrs. Reid Bros., are designed for protecting four line wires. They have brass plates with serrated edges placed close to one another; alternative plates are connected to earth and the others to the line wires.

1880. Comb lightning arresters. Lent by H.M. Postmaster-General, 1876. M. 2145–6.

These are similar to the serrated-plate protector No. 1879, except that points are substituted for the saw-teeth.

1881. Henley's lightning arrester. Lent by H.M. Postmaster-General, 1888. M. 2138.

This was patented by Mr. W. T. Henley in 1861, and has a number of star-wheels or discs with serrated edges, separated by washers and piled on a central pin within a short brass cylinder, the teeth being close to the inside surface. The cylinder is connected to line and the central pin to earth.

1882. Stars and tube lightning arrester. Lent by H.M. Postmaster-General, 1876. M. 2139.

The line wire is connected with strips of sheet copper having star points cut on the edges, and wound round the insulated axis of a brass tube connected to earth. The points of the stars are close to the inside of the tube; and there are also two combs outside affording additional paths for the flash.

1883. Globe and points lightning arrester. Lent by H.M. Postmaster-General, 1876. M. 2137.

The line wire is connected with a ring, having points nearly touching a metal globe connected to earth; there is also included in the circuit a serrated-edged strip of copper wound on a rod.

1884. Plate lightning arresters. Lent by H.M. Postmaster-General, 1888. M. 2147–9 & 2153.

The plate form of arrester is one of the most efficient yet devised; it was originally brought out by Sir C. W. Siemens in 1860.

(*a*) The original form of double-plate arrester, still used in India and the Colonies, consists of two iron plates, one connected with the "up" and the other with the "down" line, superposed on a third plate connected to earth, but separated by means of ebonite studs and washers. The plates are finely corrugated on their opposing surfaces, the corrugations on the upper plates running at right angles to those on the lower. The lightning discharges across the air-spaces between the two plates, but to prevent leakage, care must be taken to keep the surfaces free from dust.

(*b*) A later form (1878), used by the General Post Office, consists of two corrugated brass plates, tinned on their opposing surfaces to prevent oxidation, and separated by "bank-wove" paper properly paraffined; the paper is perforated by a discharge of lightning, but it is easily replaced.

(*c*) This is similar to (*a*) in having ebonite washers, but has a prepared surface like (*b*); the plates have in addition serrated edges like No. 1879, so that the lightning discharge, if not all drawn by the earth plate, can strike across from the up to the down line to be drawn off at the next station.

(*d*) This is a later form (1880) of the single-plate arrester, closely resembling (*b*) and used for terminal offices.

1885. Plate and point lightning arresters. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2142–3.

One arrester consists of a number of pointed screws set slightly below the face of a plate of vulcanite and connected together by fine wire with the line, the whole being fixed on a faced cast-iron plate connected to earth. The other arrester has a number of pins in close proximity to an earth plate.

1886. Tube and point lightning arresters. Lent by H.M. Postmaster-General, 1876 & 1888. M. 2144 & 2156.

These are early forms of the bobbin protector (*see* No. 1888). A tube is connected with the earth terminal, and the line wires are connected with terminals fitting into the tube. One of the terminals is fixed to a bobbin wound with a fine wire which almost touches the inside surface of the tube; the other has a rod, with a spiked nut on it, which screws into the bobbin.

1887. Reel lightning arrester. Lent by H.M. Postmaster-General. M. 2151.

This is a modification of an earlier form of lightning protector introduced by Mr. C. F. Varley for protecting the windings of a galvanometer; this consisted simply in twisting together the two ends of the windings so that a flash should break through this feeble insulation and so save the coil.

In the arrester shown (1878) two wires insulated with silk of different colours, one connected to line the other to earth, are twisted together and wound on a boxwood reel. The insulation is sometimes further protected by being drawn through melted paraffin.

1888. Tube and bobbin lightning arrester. Lent by H.M. Postmaster-General. M. 2152.

This is an improvement (1880) on No. 1887. The two line wires, insulated by differently coloured silk, are wound side by side round a brass cylinder and encased in a brass tube; the tube and cylinder are joined electrically and connected to earth.

1889. Bobbin cable lightning arresters. Lent by H.M. Postmaster-General, 1888. M. 2153–4.

These are intended for the protection of a submarine cable at its juncture with an aerial line.

The arrester is similar to No. 1888, but the tube is screwed and a fine covered wire wound along the thread; the whole being then enclosed in a glass case to protect it from moisture. The other arrester is of somewhat later date (1870) and has a lead tube outside the winding, this again being enclosed in glass.

1890. "Lightning bridge." Lent by H.M. Postmaster-General, 1876. M. 2150.

This protector, generally known as a boxwood and carbon lightning arrester, was patented by Messrs. C. & S. A. Varley in 1866.

It consists of two metal rods on the axis of a boxwood cylinder, with their points projecting into a small chamber nearly filled with a mixture of powdered carbon and non-conducting material, and approaching to within ·03 in. of each other; the cylinder can be turned on the pointed rods in order to bring fresh particles of the powder between them. One rod is connected with the line and the other to earth, and the carbon acts as a conductor for the high-potential discharge but not for the working current.

1891. Lightning arresters. Presented by the Russian Imperial Telegraph Office, 1877. M. 2239.

These are two similar lightning arresters of a pattern used in Russia, one being for aerial lines and the other for cables.

The arrester is placed in the circuit and has in it a fine wire that holds up a small lever against a spring. When the line is struck, the wire fuses and the lever drops on to an earth terminal. The instrument also contains point or air-gap protectors.

1892. Varley's fault-finder. Lent by H.M. Postmaster-General, 1888. M. 2157.

This is an instrument for localising a fault in one of a number of wires in an underground system, or to identify the wire under test. It was introduced by Messrs. C. F. & C. J. Varley in 1859 to obviate the then common practice of pricking through the insulation with a pin, so as to obtain a contact.

It consists of an astatic pair of needles on a curved axis and suspended by a horse-hair from a milled head. Each wire is brought successively into the jaw between the needles till, by their deflection under the influence of a current maintained in the faulty wire, the latter is found.

1893. Vertical galvanometers. Lent by H.M. Postmaster-General, 1888. M. 1994–7.

(*a*) This instrument was used by Sir W. F. Cooke in 1837, when engaged in constructing the earlier telegraph lines, and it is included in Messrs. Cooke & Wheatstone's patent of that year. It consists of an

astatic pair of needles, one inside the coil of fine wire and the other outside. The two line wire terminals on the top of the case communicate with the coil terminals inside.

(*b, c*) These two instruments were used by the Electric Telegraph Co., in 1846–48, and are similar to the above.

(*d*) Is another galvanometer used by the Electric Telegraph Co. in 1846, but is provided with removable stops and a drop-handle commutator so that it can be used as a single-needle instrument.

1894. Trough battery. Lent by H.M. Postmaster-General, 1888. M. 2237.

This form of Daniell battery was used by the Electric and International Telegraph Co., and by the General Post Office in 1864; similar ones are still in use. The trough is made of teak 12·25 in. long, 6 in. wide, and 5·25 in. deep, inside measure, and is divided into six cells by means of slate partitions. It is then coated throughout with marine glue, and each cell is subdivided by a porous plate of porcelain ·18 in. thick. A zinc plate 3·25 in. by 1·87 in. is suspended in one division, and the copper plate 3 in. sq. in the other; a copper strip riveted to the copper and cast into the zinc connects the two. Water acidulated with sulphuric acid is placed with the zinc, and crystals of copper sulphate with the copper plate.

1895. Meidinger's cell. Presented by the Russian Imperial Telegraph Office, 1877. M. 2236.

This form of battery, largely used in Germany and Russia, is a modification of Daniell's, but is a "gravity" battery, in which the porous partition is dispensed with. It consists of a glass cell containing a smaller glass vessel, like a tumbler, resting on the bottom. In the latter a copper cylinder is placed and to it is attached an insulated copper wire terminal. The zinc cylinder is supported by a projecting ledge on the inside of the cell. A porcelain lid covers the whole, but through an aperture in its centre an inverted Florence flask, whose neck is partly closed by a cork, is inserted and reaches halfway down into the tumbler. In the flask are crystals of copper sulphate and a solution of magnesium sulphate, and as the copper sulphate dissolves it passes to the bottom of the tumbler owing to its density. When the solutions have completely diffused, the cell must be recharged.

1896. Varley's secondary battery. Lent by H.M. Postmaster-General, 1888. M. 2238.

This form of Grove's gas battery was brought out by Mr. Varley in 1858, and used by the Electric Telegraph Co. for transmitting daily telegraphic time-signals through long lengths of wire; such a large number of magnets having to be simultaneously influenced, a single powerful but momentary current was required.

The battery consists of 12 vulcanite cells, each with a central ridge at the bottom, 1 in. high. Mercury is poured into each cell, but not in sufficient quantity to cover the ridge, and the cells then nearly filled with dilute sulphuric acid. Into each cell is placed a carbon plate, and one of zinc, both dipping into the mercury. Connection between the cells is made by platinum wires passing through the walls and exposed below the mercury. The cells could give a primary current, but were charged in 30 minutes by a battery of double the number of pairs in the reverse order.

1897. Resistance box. Lent by H.M. Postmaster-General, 1888. M. 2159.

This box of resistances was designed by Mr. C. F. Varley in 1862 for use in line-testing.

Brass plates, insulated from one another by being fixed on a vulcanite base, are in communication below through wires of known resistance. Brass plugs fit into spaces between the plates, so that one resistance after another from infinity to 1 ohm can be short-circuited as required. The box containing the coils is filled up with resin.

1898. Resistance box. Lent by H.M. Postmaster-General, 1888. M. 2158.

This is a portable form of circular sliding resistance box.

Pieces of brass are fixed in a circle on a base of vulcanite and with these are connected wooden cylinders, wound with sufficient covered wire to give resistances of 1, 2, 3, up to 30 ohms; the whole of the coils are coated with wax and enclosed in a box. One terminal is connected with the blank in the circle and the other with the central sliding handle, by moving which the coils left in the circuit can be quickly altered.

1899. Early Bell telephone (1877). Received 1906. M. 3446.

This form of magnetic telephone, patented by Prof. Alexander Graham Bell in 1876, was one of the earliest to be brought into practical use.

The instrument consists of a permanent horse-shoe magnet having short coils mounted upon its poles, while in front of the coils is a thin iron disc or diaphragm carried by a block of wood, through which there is a hole communicating with an external mouth or ear piece. The coils are joined in series, and connected by a line wire with those of a similar instrument, the circuit being completed by connecting one terminal at each end with the earth. Speech uttered into the mouthpiece of one of the instruments sets the diaphragm into a state of vibration, and its movements produce variations of the number of lines of magnetic force passing through the coils. Alternating currents, corresponding to the pitch, amplitude, and timbre of the sound, are consequently induced, and are transmitted to the second instrument. On passing through the coils of the latter, these currents, by producing changes in the magnetisation, cause variations of the force with which the diaphragm is attracted. This is consequently made to repeat the movements of the first diaphragm, and the original sounds are reproduced. Each instrument is used alternately as a transmitter, into which the words are spoken, and as a receiver to reproduce the sounds.

As the original mouthpieces were missing, those exhibited were added in the Museum in 1906.

In modern telephony distinct instruments are employed for transmitting and receiving. The receivers generally used are similar in principle to the instruments shown, but considerably modified in design; modern transmitters, however, are altogether different.

1900. Telephonic receiver. Presented by T. A. Edison, Esq., 1880. M. 1484.

This construction of receiver was tried by Mr. Edison as a means of intensifying the articulation of a telephone, so that it should be heard by a large audience. The action of the apparatus depends on the fact that the friction of a metal strip sliding over a chemically-wetted surface diminishes when a current traverses the point of contact.

A thin diaphragm of mica, 4 in. diam., forming the top of a box, carries at its centre a platinum strip, which presses against a porous cylinder enclosed by the box and rotated by mechanism; the cylinder is continuously moistened by a felt roller saturated with a solution of potassium iodide. When receiving, the mica disc vibrates similarly to the membrane of the transmitting telephone, owing to the fluctuations of the current varying the friction between the cylinder and the strip; the articulation so obtained, although loud, was indistinct.

1901. Gower-Bell telephones. Received 1908. M. 3534.

Owing to the very small electric currents developed in the magnetic telephone as arranged by Graham Bell (*see* No. 1899), it could be used efficiently as a transmitter over comparatively short distances only. Transmitters were consequently introduced in which currents from batteries were utilised, and the acoustical effects were employed to produce variations of the resistances of the circuits. Undulating currents were thus obtained, which, by means of magnetic receivers, were made to reproduce the exciting sounds. At first the transmitter and its battery were placed in circuit with the line wire and the distant receiver, and as the variations in resistance produced in the transmitter were small compared with the total resistance, the changes in the current were correspondingly small. This difficulty was overcome by using an induction coil, the primary of which was in circuit with the transmitter and battery, while the secondary was connected with the line.

T. A. Edison in 1877 constructed an instrument of this type, the action of which depended upon changes in the resistance of carbon with variations of pressure, while, in 1878, Prof. D. B. Hughes introduced his "microphone," which utilised the variations of the resistance of substances in loose contact placed in the neighbourhood of the sounds to be reproduced. Carbon was found to be the most suitable material, and many forms of carbon transmitters embodying the principle of Hughes's apparatus are now employed.

The instruments shown are of a type which has been used by the British Post Office, in which a carbon transmitter, patented by Mr. F. A. Gower in 1880, is employed. This consists of eight carbon pencils, supported between eight carbon blocks and one central block, all the blocks being recessed to receive loosely the reduced ends of the pencils. Four of the outside blocks are connected by means of a copper strip with one terminal of the battery, while the remaining four are connected, through the primary of an induction coil, with the other. The blocks are mounted upon a thin deal board which constitutes the diaphragm, and is enclosed in a wooden casing fitted with a porcelain mouthpiece.

Two double-pole Bell receivers—not shown—are employed, and, when not in use, are carried in the forked ends of switch-levers placed at the sides. The arrangements are such that the bell circuit can be closed only when the levers are depressed by the receivers; when, however, the receivers are removed, the levers are raised by the action of springs, and the transmitting and receiving portions of the instrument are switched into circuit.

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CONTENTS.

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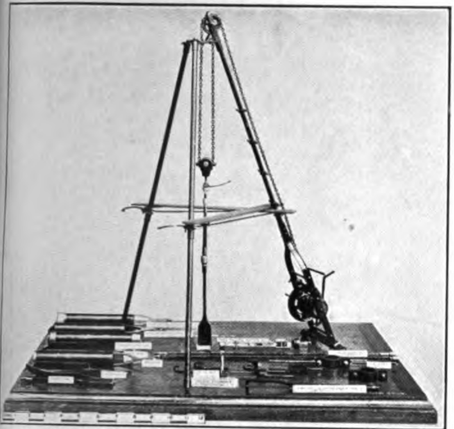
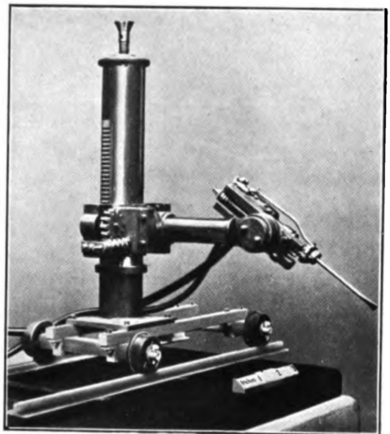
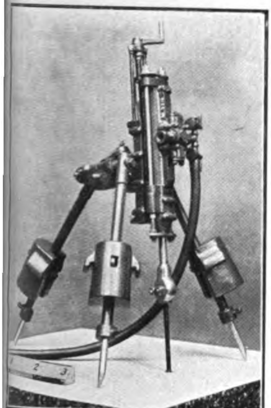
Plate I.



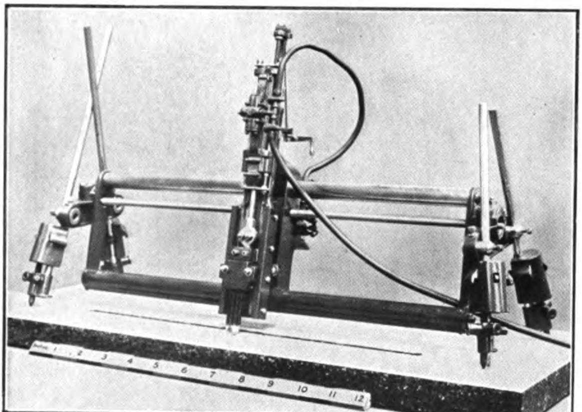
1. Boring plant, p. 8.



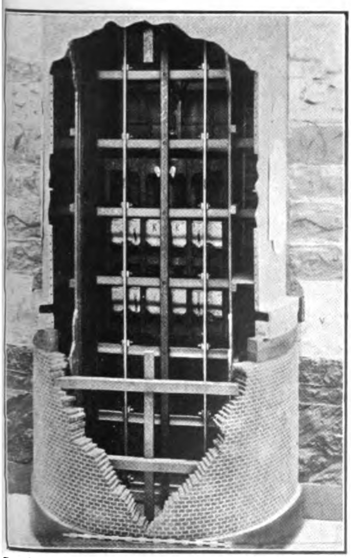
2. Early rock drill, p. 12.



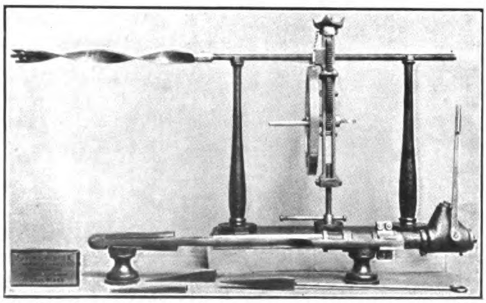
3. Rock drill, p. 15.



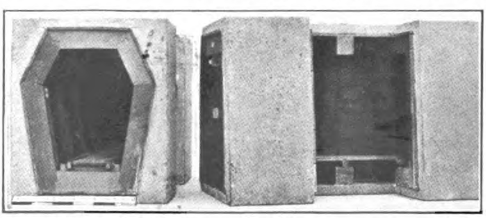
4. Bar channelling machine, p. 15.



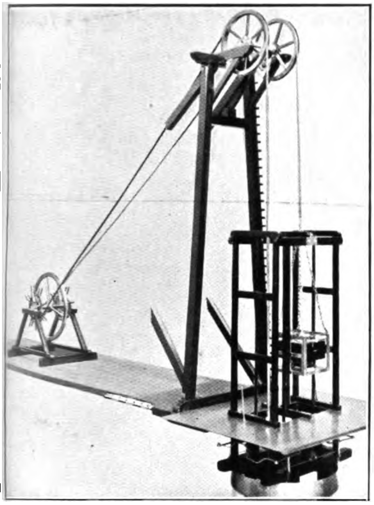
5. Shaft tubbing & cage, p. 23.



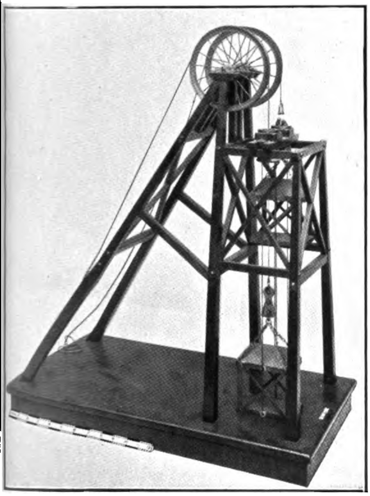
6. Boring and wedging apparatus, p. 18.



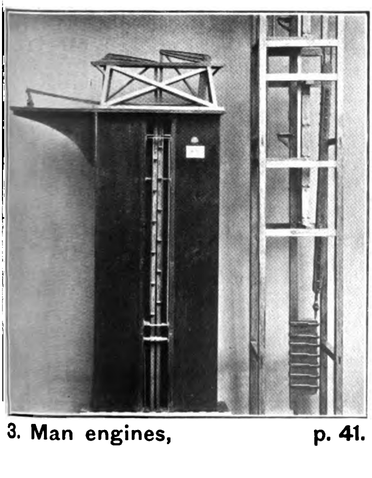
7. Level timbering, p. 27.



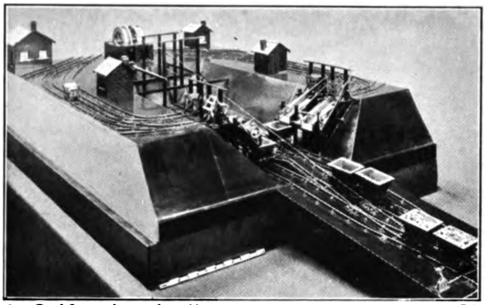
1. Shaft and cages, p. 35.



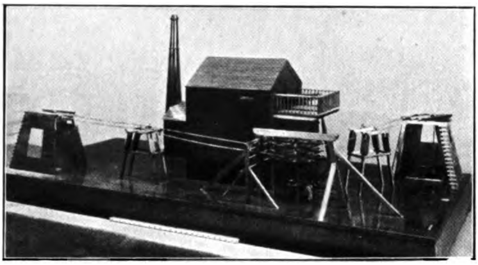
2. Pit-head gear, p. 39.



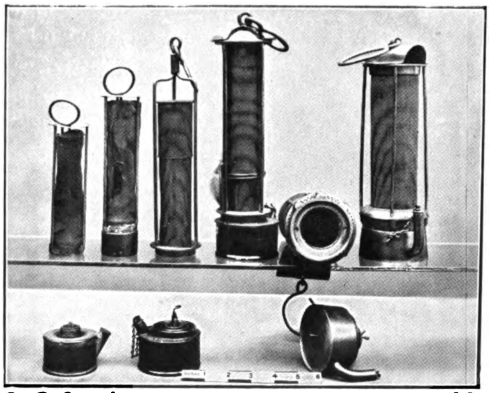
3. Man engines, p. 41.



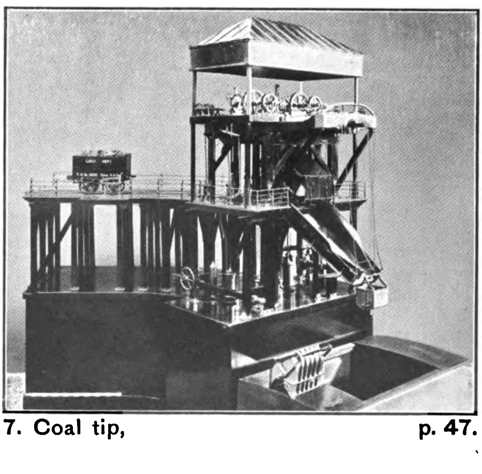
4. Self-acting incline, p. 31.



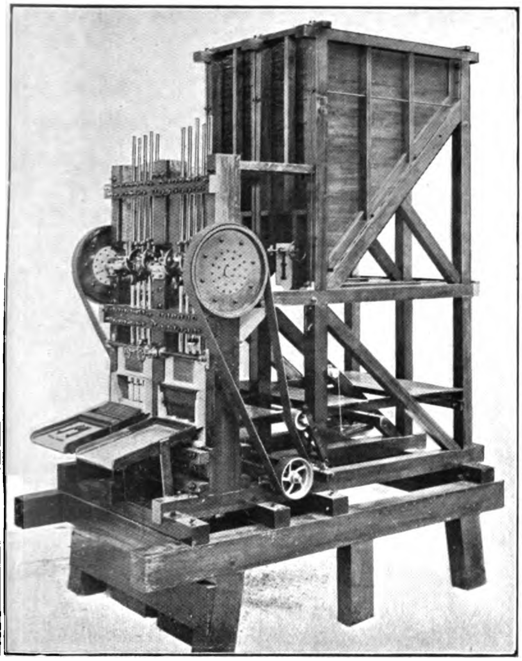
5. Steam whim, p. 34.

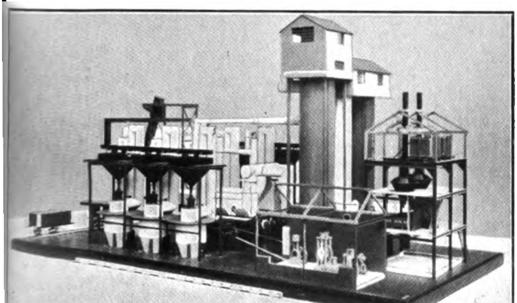


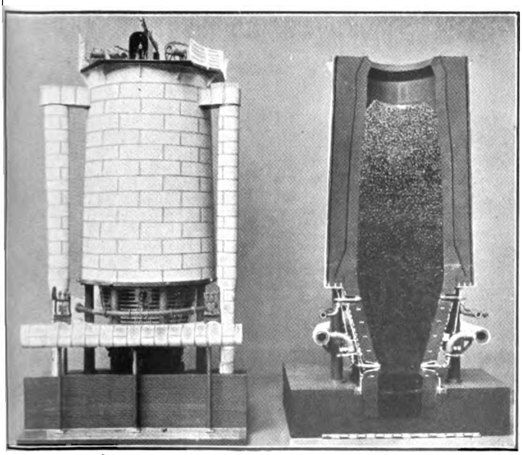
6. Safety lamps, p. 44.

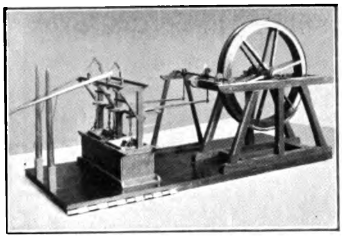


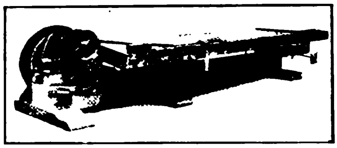
7. Coal tip, p. 47.

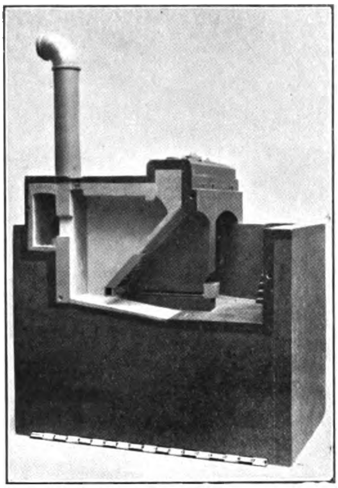

1. Stamp battery, p. 59.

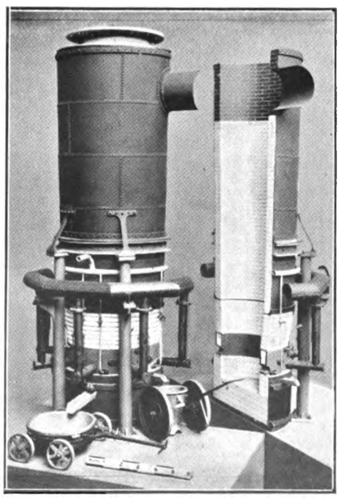

2. Producer gas plant, p. 77.

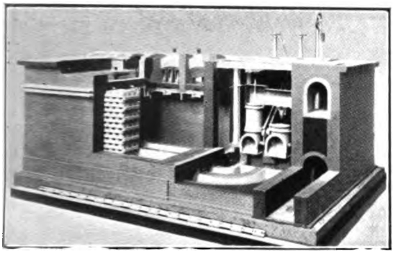

3. Blast furnace, p. 82.


4. Jigging machine, p. 62.

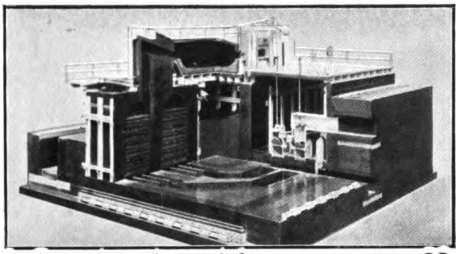

5. Ore concentrator, p. 67.


6. Siemens's producer, p. 76.

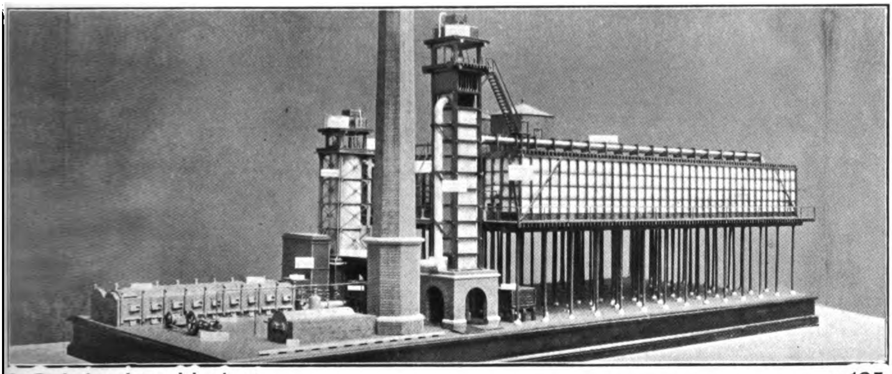

7. Pilz furnace, p. 86.



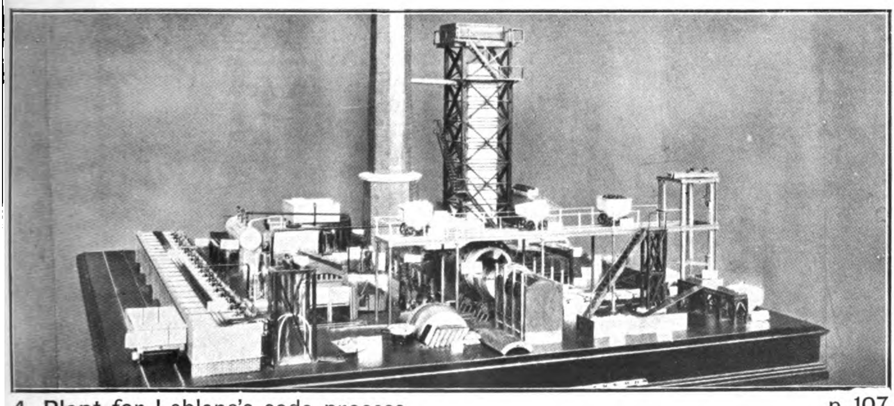
1. Crucible steel furnace, p. 90.



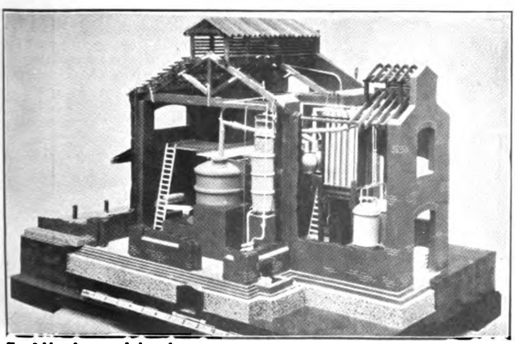
2. Open hearth steel furnace, p. 98.



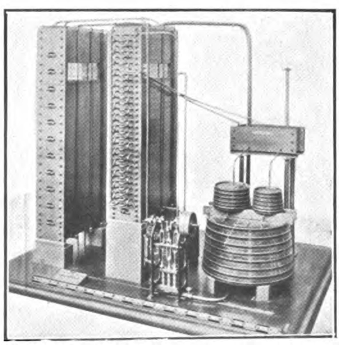
3. Sulphuric acid plant, p. 105.



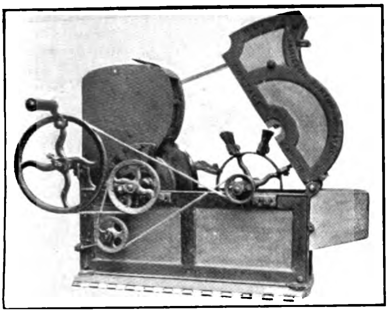
4. Plant for Leblanc's soda process, p. 107.

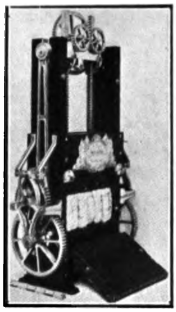


5. Nitric acid plant, p. 109.

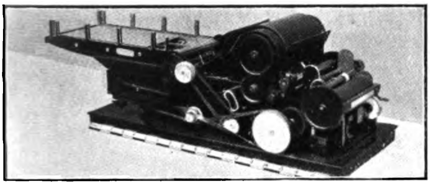


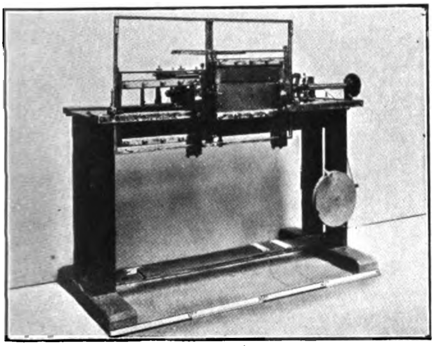
6. Coffey's still, p. 111.

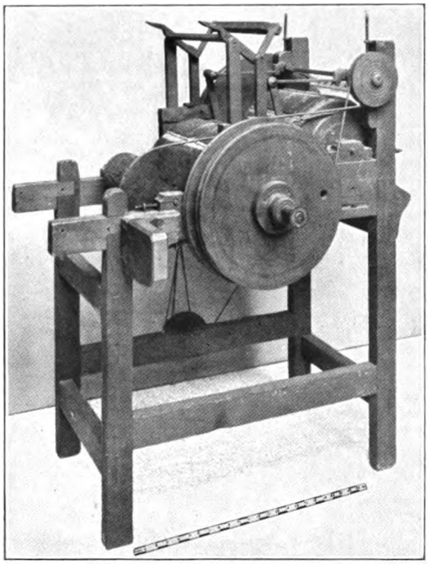

1. Cotton gin, p. 119.

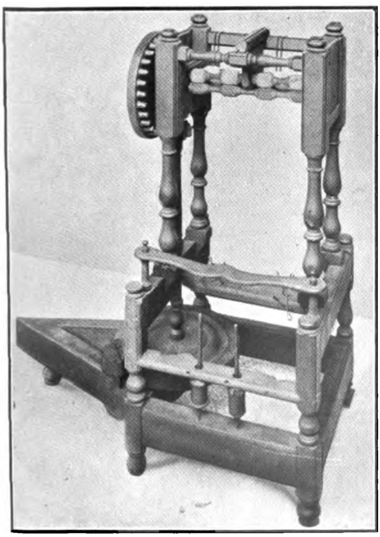

2. Press, p. 120.


3. Spinning wheel, p. 126.


4. Scutching machine, p. 121.


5. Card-making machine, p. 124.


6. Carding engine, p. 121.


7. Spinning machine, p. 127.

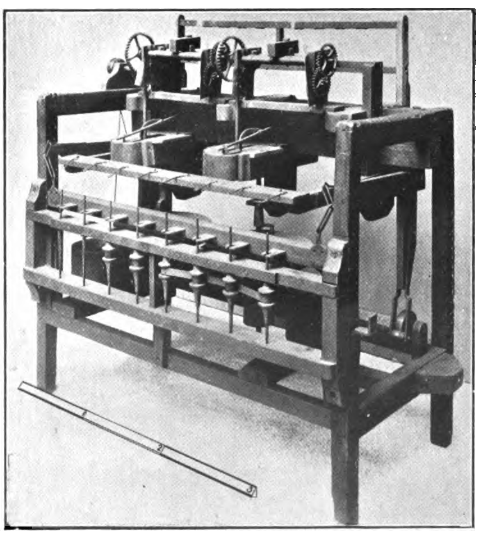
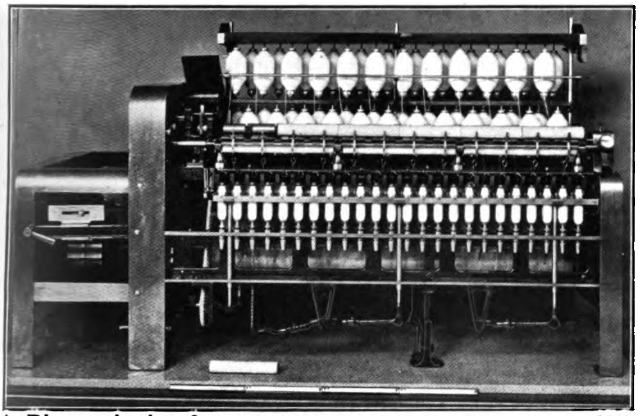
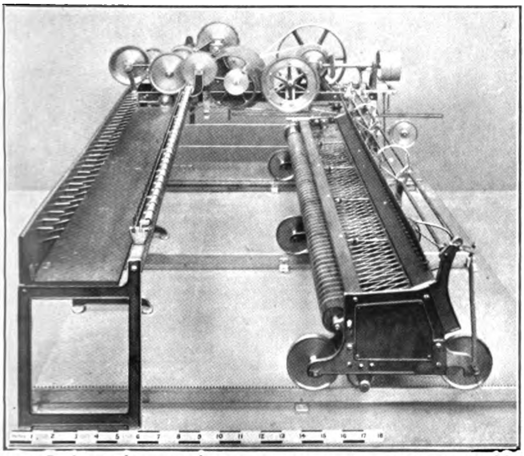

8. Improved spinning machine, p. 128.

Plate VI.

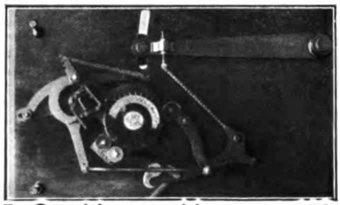


1. Ring-spinning frame, p. 130.

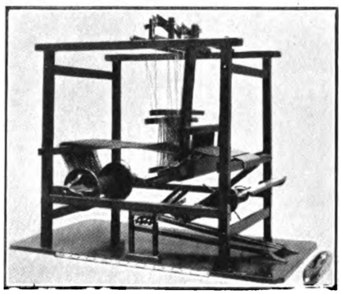
2. Silk-throwing, p. 143.



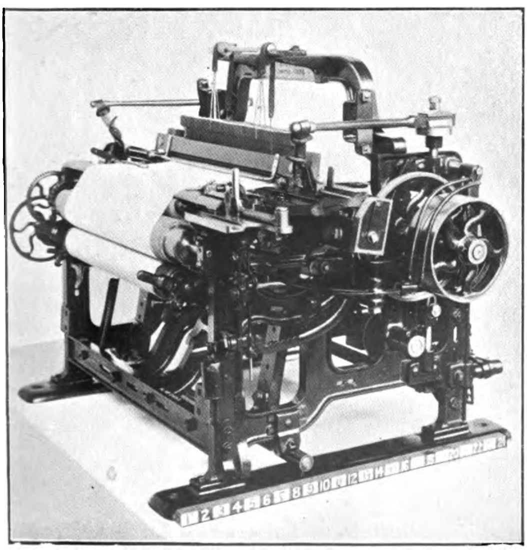
3. Self-acting mule, p. 132.



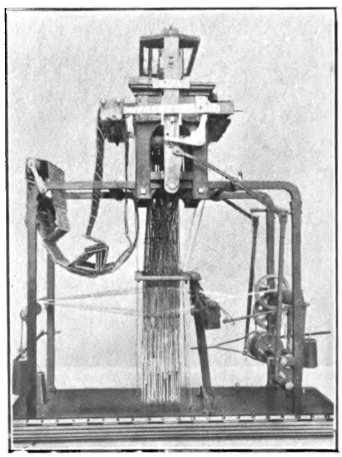
5. Combing machine, p. 140.



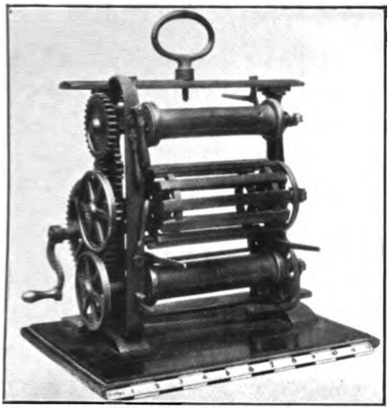
6. Hand loom, p. 147.



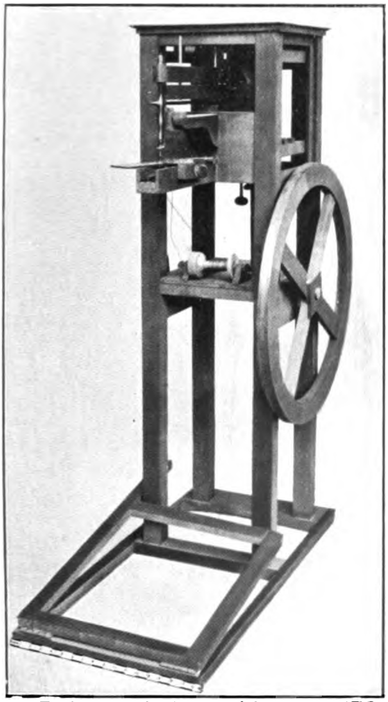
4. Power loom, p. 152.



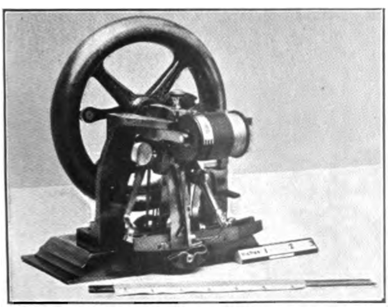
7. Jacquard apparatus, p. 155.



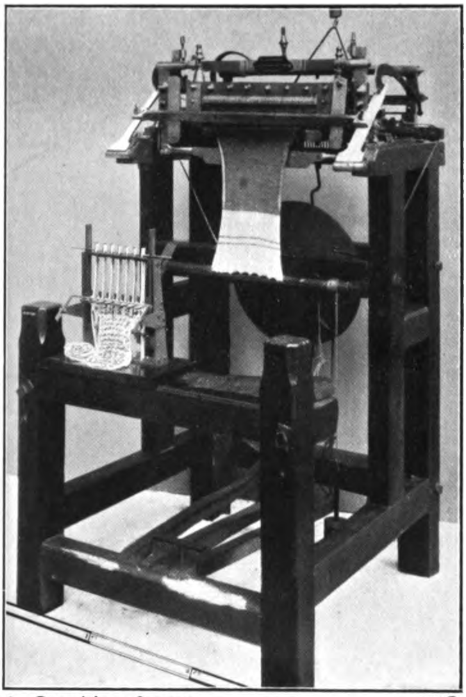
1. Teasing mill, p. 163.



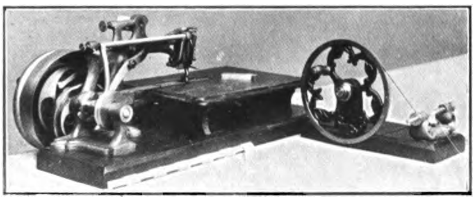
2. Thimmonier's machine, p. 170.



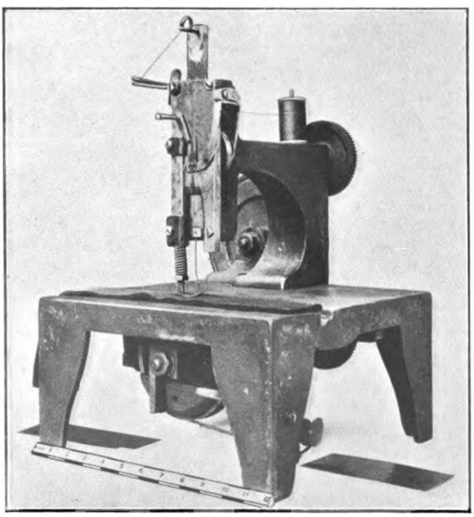
3. Howe's sewing machine, p. 171.



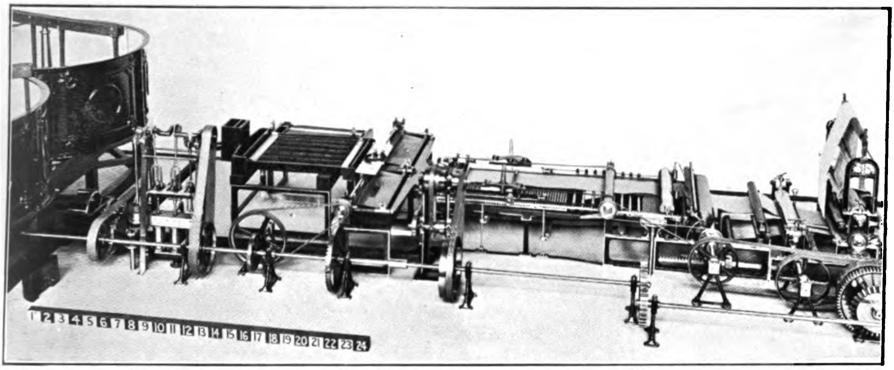
4. Stocking frame, p. 158.



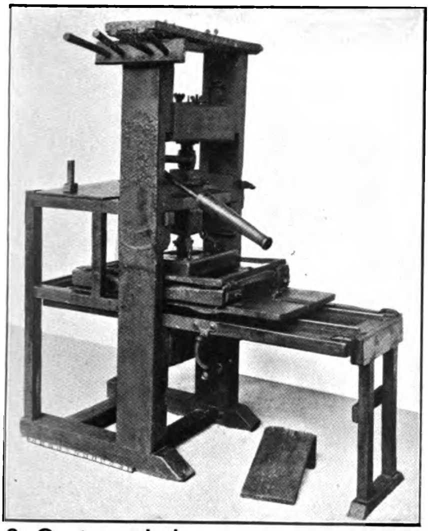
5. Thomas's sewing machine, p. 172.



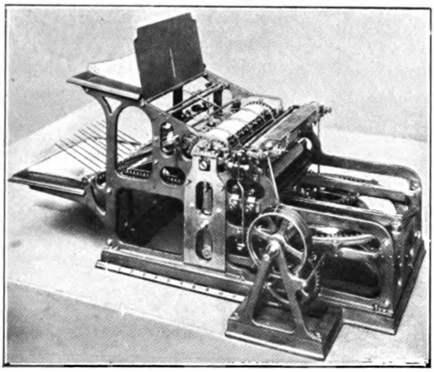
6. Singer's sewing machine, p. 172



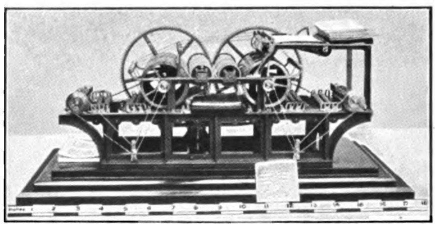
1. Paper-making plant, p. 189.



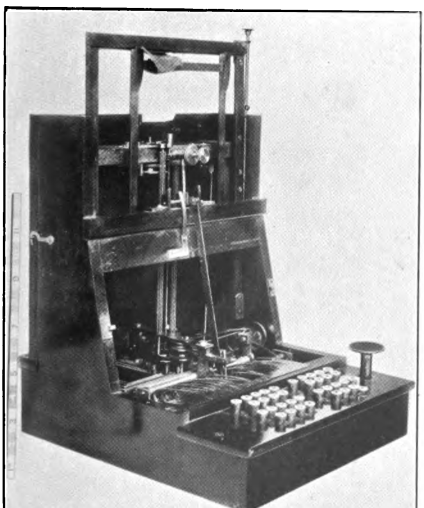
2. Caxton printing press, p. 201.



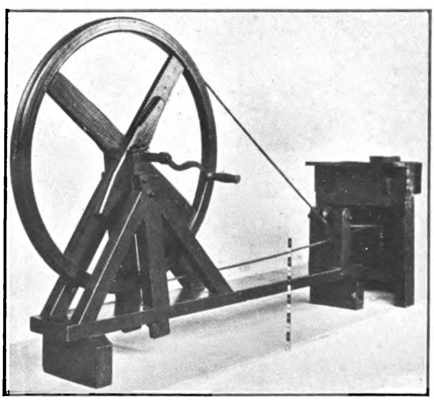
4. Single printing machine, p. 203.



5. Perfecting printing machine, p. 202.

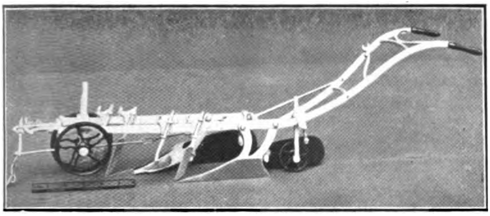


3. Pratt's typewriter, p. 214.

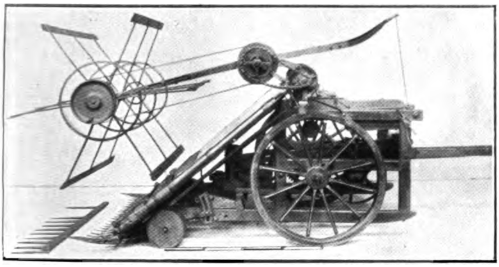


6. Potter's wheel, p. 223.

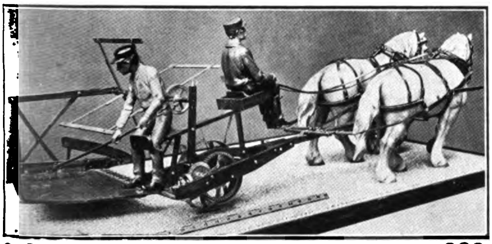
Plate IX.



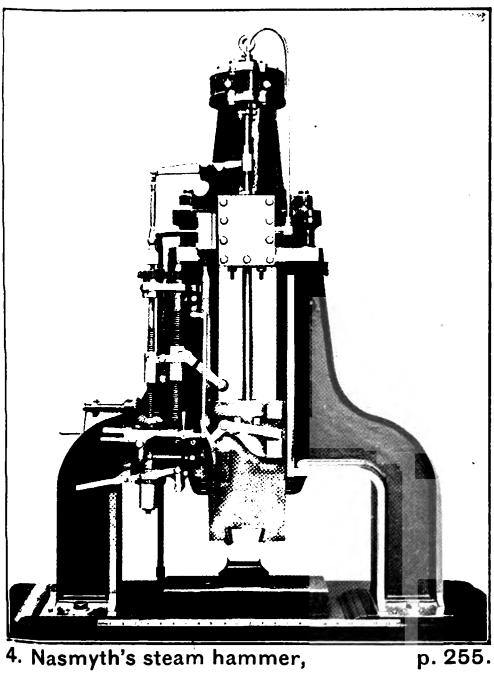
1. Double-furrow plough, p. 228.



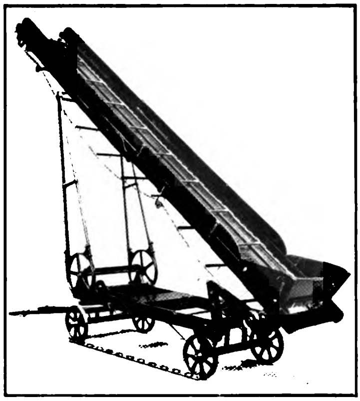
2. Bell's reaping machine, p. 232.



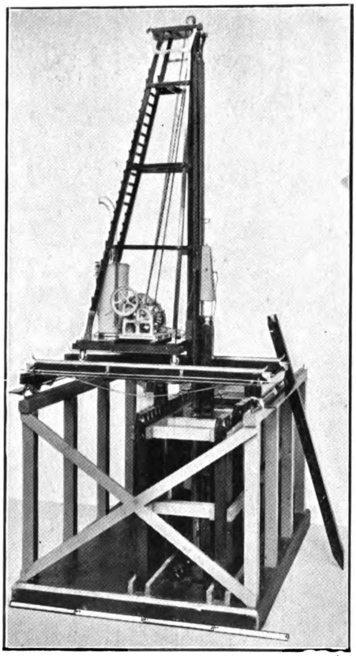
3. McCormick's reaping machine, p. 233.



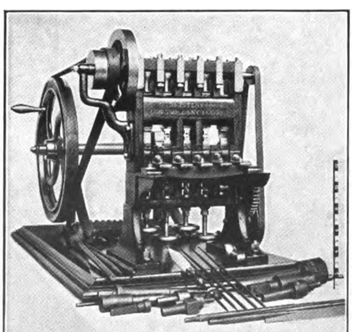
4. Nasmyth's steam hammer, p. 255.



5. Hay elevator, p. 234.

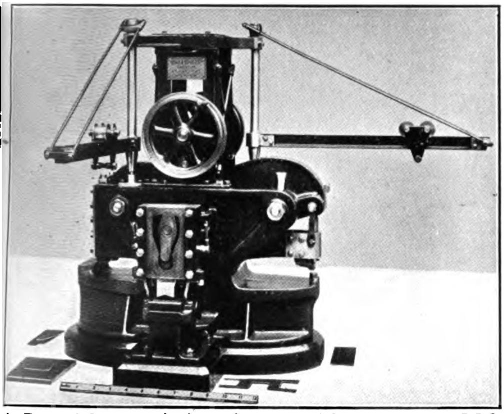


6. Pile driver, p. 254.

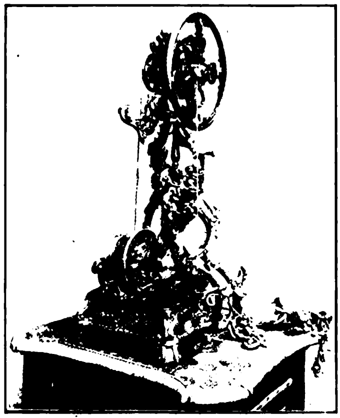


7. Forging machine, p. 259.

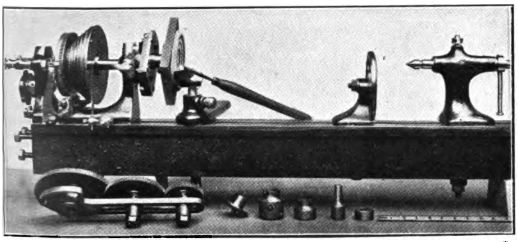
Plate X.



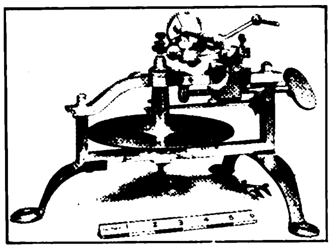
1. Punching and shearing machine, p. 263.



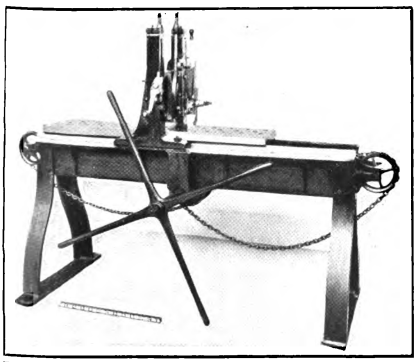
2. Rose engine, p. 265.



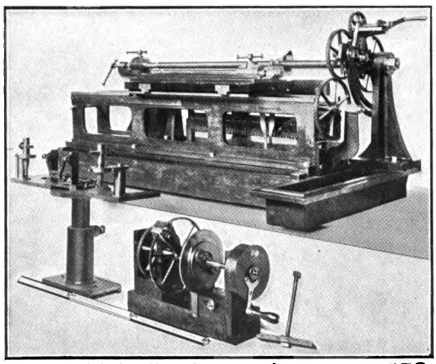
3. Ornamental lathe, p. 268.



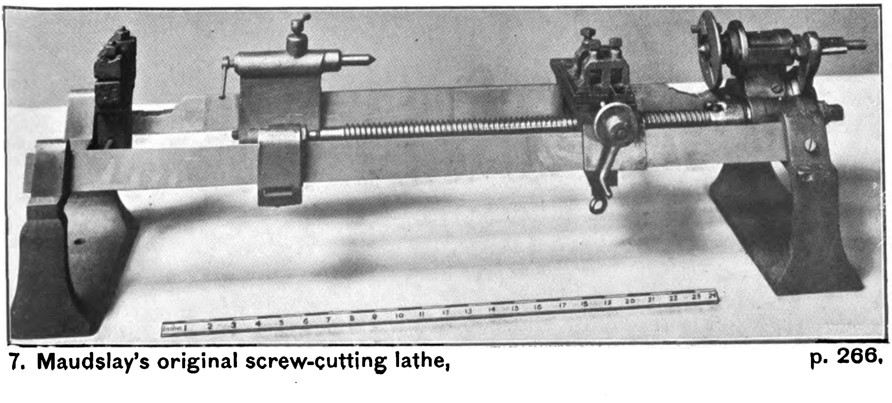
4. Wheel-cutting engine, p. 275.



5. Roberts's planing machine, p. 272.

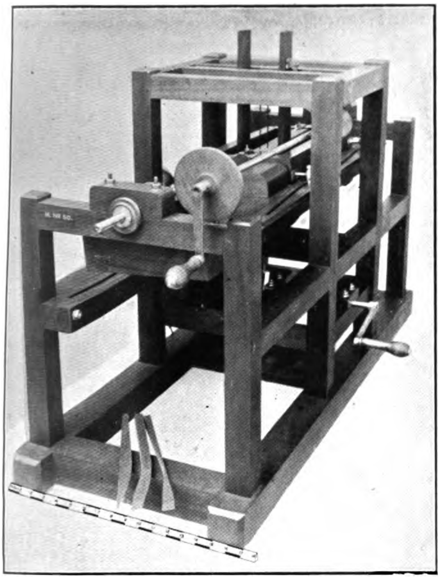


6. Donkin's dividing engine, p. 279.

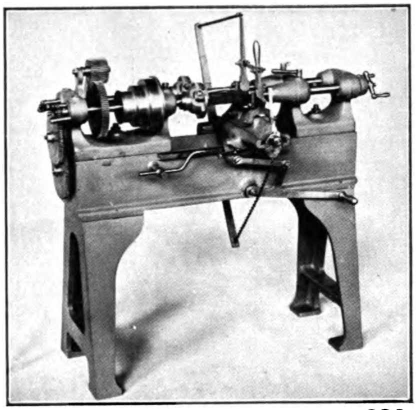


7. Maudslay's original screw-cutting lathe, p. 266.

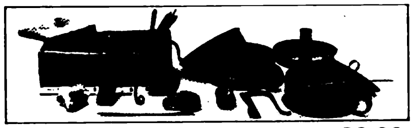
Plate XI.



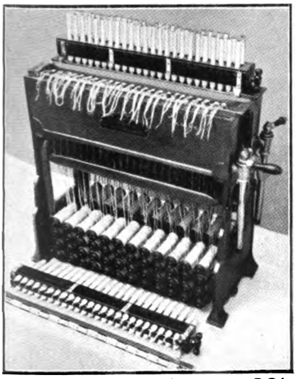
1. Saw-frame for ships' timbers, p. 284.



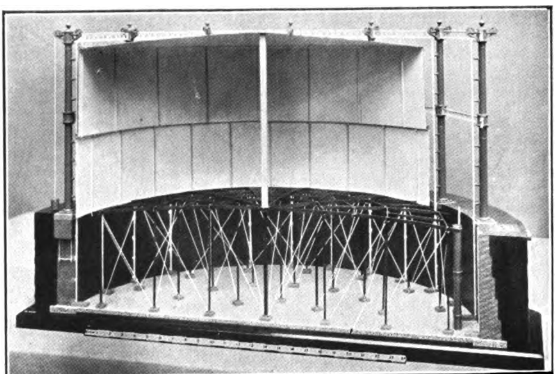
2. Copying lathe, p. 286.



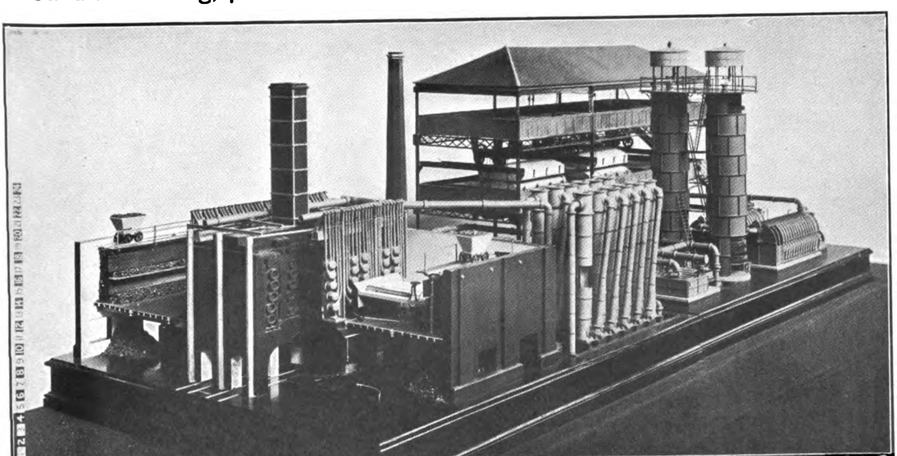
3. Tinder boxes, pp. 289-90.



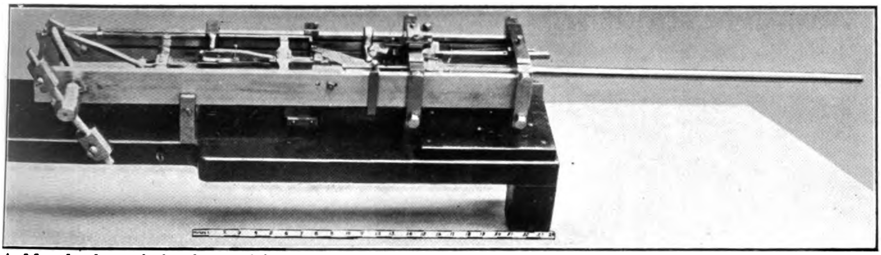
4. Candle moulding, p. 291.



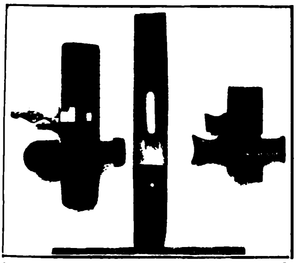
5. Gasholder, p. 294.



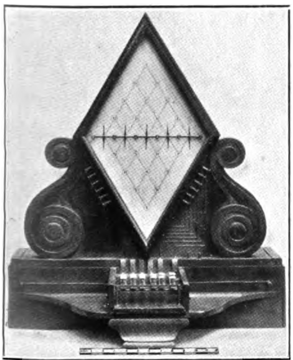
6. Gas works and purifying house, pp. 292-3.



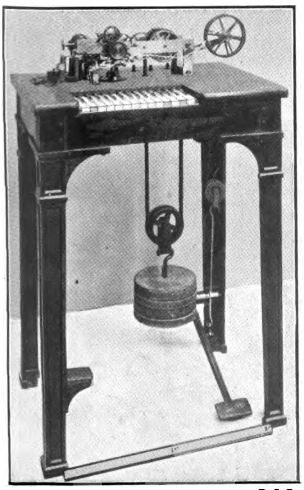
1. Maxim's original machine gun, p. 313.



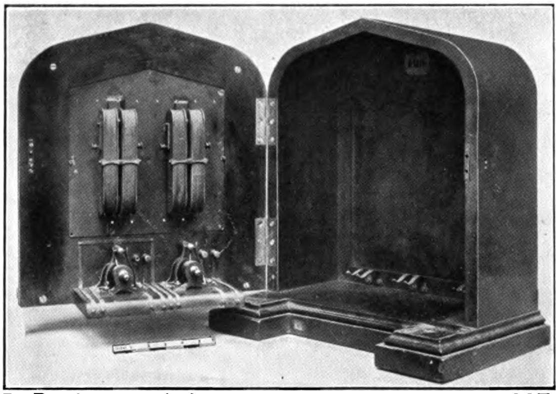
2. Wooden locks, p. 318.



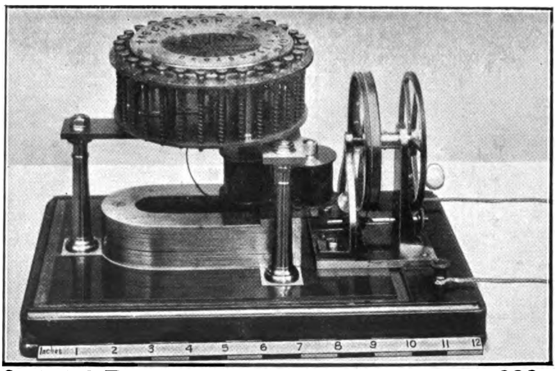
3. Five-needle instrument, p. 326.



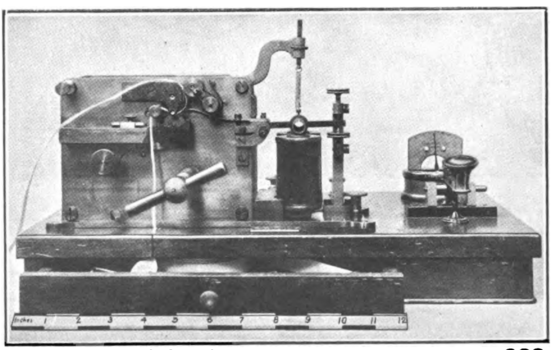
4. Type printer, p. 340.



5 Double-needle instrument, p. 327.



6. A B C Transmitter, p. 333.



7. Siemens's inkwriter, p. 338.